1150-7

Less Noise Better Hearing

1938 edition

JACOBSON & COMPANY, Inc.
1609 Vine Street—Rittenhouse 3683
PHILADELPHIA, PA.

Acoustical Engineers and Contractors

DISTRIBUTORS FOR

CELOTEX
REG. U. S. PAT. OFF.

ACOUSTICAL PRODUCTS

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Less Noise Better Hearing

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Printed in U. S. A.

4th Edition

THE CELOTEX CORPORATION

919 N. MICHIGAN AVENUE • CHICAGO, ILLINOIS

In Canada

DOMINION SOUND EQUIPMENTS, LTD.

Distributors for Celotex Acoustical Products

A. I. A. No. 39b.

ACKNOWLEDGMENT

For public appreciation of the usefulness of acoustical material in bringing quiet and good acoustics to modern structures, and for the recognition which has won Celotex its leadership in this field, The Celotex Corporation gratefully acknowledges the contribution of the architectural profession.

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Foreword — 1930

The efficacy of any acoustical treatment will always depend in large measure upon the degree of technical skill, experience, and scientific acoustical knowledge applied in analyzing the conditions to be corrected.

There is not, nor ever can be, a monopoly of such knowledge. The sum of available knowledge in architectural acoustics, as in our other sciences, is nothing more than the combined experience, in laboratory research or actual practice, of organizations or individuals.

During the six-year period covering the development of Acousti-Celotex, thousands of dollars have been invested by The Celotex Company in acoustical research and development.

Part of this money has been invested in fostering special investigations and general research in six independent acoustical laboratories, and part in the promotion of experiments to determine the physiological and psychological effects of noise on human beings. The information developed has been made freely available to all who are interested, including the active competitors of Acousti-Celotex.

This policy of making such knowledge the common property of all who can benefit by its use is a concrete expression of The Celotex Company's belief that the acoustical industry can progress only in proportion to the degree in which each member of the industry contributes to those basic assets which properly belong to the industry, as a whole, and to the public.

As a further contribution to this cause, The Celotex Company participated in organizing the Acoustical Society of America, which is not limited to architectural acoustics but which covers the entire field of acoustical research.

Good acoustical materials and skilled acoustical engineering service can never be sold at bargain counter prices. Those which might be considered costly from the viewpoint of superficial price comparison are likely to prove the least expensive, since both the material and its installation will represent the results of thousands of hours and dollars invested in research and development.

The acoustical engineering service offered by The Celotex Company commands the latest and most complete scientific acoustical knowledge and technical practice.

This service is available to all requiring acoustical installations and is rendered through local representatives in every part of the country.

THE CELOTEX COMPANY

1931 · 1932 · 1933 · 1934 · 1935 · 1936

THESE PAST YEARS BRING US TO TOMORROW

1937 · 1938

And these years have emphasized three things:

1. Eight years passage has emphasized the unchanging truth of our 1930 Foreword. There is little to add.
2. Acoustical material for less noise and better hearing is no longer considered a luxury.
3. Good acoustical material can never be sold at bargain counter prices. Those which might be considered costly from the viewpoint of superficial price comparison are likely to prove the least expensive, since both the material and its installation will represent the results of thousands of hours and dollars invested in research and development.

• • •

Acousti-Celotex has been improved and its cost lowered. Celotex has acquired Calicel—an acoustical tile of appealing beauty, made of expanded stone. Vibrafram (formerly Heerwagen Tile) is another noteworthy addition to the Celotex line. A radical departure from conventional porous acoustical materials, this practical expression of the principle of sound absorption by diaphragmatic action has engaged the interest of acoustical engineers in the Old World as well as the New.

Absorbex is another addition to the line which combines great structural strength and fire resistance with a surface texture that has won for it a wide acceptance.

Q-T Ductliner, a specially designed sound-absorbent, thermal insulating, fire and moisture resistant product, planned especially for air conditioning systems, meets another growing need.

Celotex Merchandising Policy remains unchanged. Celotex Acoustical Products are sold regionally by exclusive distributors. With their organizations of competent acoustical engineers, salesmen and application mechanics, the most efficient and economical use of these products is always assured.

Selecting an Acoustical Material

AN acoustical material is a material which can be satisfactorily employed to do a job of noise quieting or acoustical correction.

Such jobs vary widely, as per example: Providing good acoustics for speech and music in a convention hall seating thousands of people . . . providing good acoustics in a courtroom where speech only is heard . . . providing good acoustics in a music hall, where speech is a minor consideration . . . The acoustical requirements of churches differ,—the Roman Catholic Church calls for different treatment than a Christian Science Church . . . Lecture room treatment is inadequate in broadcasting studios or sound movie theatres . . . Quieting noise in general offices is a different problem from quieting restaurants, kitchens, swimming pools, gymnasiums, hospital corridors.

From the material standpoint, different jobs place different requirements on an acoustical material. In many cases, acoustical material originally installed has been subsequently and successfully replaced by acoustical material of a different type.

Out of a quarter century of experience time has proved the importance not only of absorption and cost of maintenance in an acoustical material but of certain other factors as well.

In an effort to assist architects and owners in the selection of acoustical material, these comments are offered.

Sound Absorption

The Acoustical Materials Association, of which Celotex is a charter member, was formed by manufacturers of acoustical materials for the purpose of furnishing architects and others, reliable sound absorption coefficients obtained under identical conditions and therefore comparable. In the choice of the test method and other technical matters, the Association has been guided by the recommendations of its Technical Advisory Committee which is composed of leading authorities in the field of architectural acoustics.

Uniformity

A. M. A. coefficients therefore provide guidance in comparing sound absorption. Since these are based on test samples, the purchaser should also give consideration to the probable uniformity of product. It is not intended here to suggest that manufacturers will deliberately fake test samples. But certain types of acoustical materials, by the very nature of their manufacture or application, unavoidably introduce an element of variation that is lacking in others, or present to a lesser degree.

Maintenance

The history of acoustical materials establishes to the satisfaction of any student the conviction that maintenance is second in importance only to sound absorption, and should indeed be considered simultaneously with it.

In the manufacturing process it is no trick to obtain a desired color in a new, clean acoustical material by integral coloring or by surface paint or stain, without injury to sound absorption. But what can be done in future years when the material becomes dirty, unsightly and absorbs light?

The cleaning of acoustical material has been attempted by commercial wall paper cleaners, by special vacuum cleaner attachments, by sandpaper and by washing with soap and water. All have their limitations. Sooner or later in the majority of cases painting becomes the necessary method of renovation. What effect on the sound absorption will repeated paintings,—ordinary paint applied by ordinary painting methods,—have?

Wherever acoustical material is relied on for good light reflection paintability is vitally important. In any case methods and costs of maintenance should be thoroughly investigated.

Permanence

The composition of an acoustical material, and the method of its application are important factors in its

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

probable length of service and the cost of repairs. Absence of matter that will supply food to rats, mice, other vermin and insects, freedom from termite attack and dry rot, are points on which the wise purchaser will assure himself. Materials that flake or peel, especially when cleaning is attempted, introduce hazards that may be unpleasant or, as in hospitals and restaurants, dangerous.

Acoustical material is commonly applied on ceilings by cementing to plaster or concrete, or it may be mechanically attached in some fashion. Probably the most satisfactory safeguards to the purchaser are extensive experience back of the product and application method, and the responsibility of the applicator.

Abrasive Strength

In the majority of cases acoustical treatment is not subject to physical contact after application. But this factor is important wherever acoustical material is applied on lower wall surfaces, and in gymnasium and recreation rooms where it is subjected to the impact of basketballs, baseballs, etc.

Combustibility

It would be desirable if rubber, that useful servant of mankind in a thousand ways, were incombustible by nature.

Similarly, it would be desirable if all acoustical materials were incombustible by nature. In the manufacture of incombustible acoustical material, however, offsetting disadvantages including higher costs are commonly encountered.

Some incombustible acoustical materials are commonly installed by fastening to wood strips which first are attached to walls or ceilings,—an incongruity which is plain but which sometimes passes unnoticed.

Shouting "fire" frequently starts panics. In panics people do not think clearly. Let us examine this point intelligently, mentioning parenthetically that Celotex manufactures incombustible acoustical material.

First, there are no fireproof building materials. A wall of concrete and steel offers a greater resistance to fire than one of wood, but since it is not fireproof the difference is only a matter of degree. Structural steel, in fire-safe construction, must be encased in masonry.

Millions of square feet of acoustical material of varying degrees of combustibility have been installed in the past quarter-century in all types of buildings. We know of no fire where the presence of acoustical material has caused loss of life or permanent injury or has contributed hazardously to the spread or duration of fire. On the contrary, in some of the few instances of record, even a combustible acoustical material has retarded the spread of fire by virtue of its heat insulating qualities.

Fire hazard should be considered in the selection of an acoustical material, but always in relation to the nature of job involved, and the record of experience behind specific materials compared.

Alteration Problems

In building alterations or extensions it is frequently necessary to repair or add to earlier installations of acoustical material. Thought should be given to the purchaser's ability in later years to obtain an additional supply of the same material. In this respect, the past history of a product is perhaps the safest guide.

In connection with future alterations, the salvageability of acoustical materials once installed is also deserving of consideration. Investigate what can be done in this direction, and obtain for record purposes estimates of cost per unit area.

Resistance to Moisture

In natatoriums, dishwashing rooms and kitchens this factor is of especial importance. It is not wise to depend on normal atmospheric humidity, regardless of air-conditioning measures. The ability of the acoustical material and its method of application to stand up under such severe conditions should be checked.

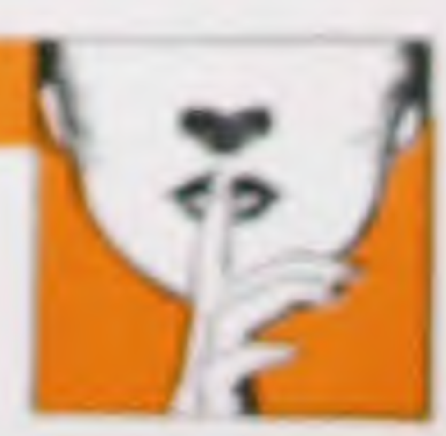
Heat Insulation

If the ceiling to be covered with acoustical material happens also to be immediately below the roof, this is a factor also deserving of investigation. Many acoustical materials are in themselves excellent heat insulators, so that wise selection can solve two problems in one investment.

Appearance

Here two admonitions are urged: (1) Study the appearance of the acoustical material as it will look installed in place, not as it looks held in the hand. (2) In weighing appearance, remember the artistic precept: Form follows function. A material, machine or building should be designed efficiently to perform its function. Where practical advantage is to be sacrificed to aesthetic consideration, be sure the choice is weighed.

In the finished job appearance of any acoustical material, much depends on the skill and experience of the installing mechanics and on the interest taken by the distributor in planning and supervising the work.



Q-T DUCTLINER

TRADE MARK

Absorbs Air-Borne Sound in All Duct Systems

Because a duct is more or less a "speaking tube," sounds entering it are freely transmitted through the system. Q-T Ductliner is an acoustical material designed especially for duct lining in air conditioning systems to absorb these noises.

Moisture-Resistant

Because materials used for lining ducts of air conditioning systems are constantly subjected to humidity, it is vital that the acoustical lining used be moisture resistant. Q-T Ductliner amply satisfies this requirement.

Fire Resistant

Prepared in rigid block form, composed of rock wool and a special binder, it will not smoulder or support combustion.

Low Thermal Conductivity

Q-T Ductliner has a conductivity of 0.30 Btu per hour, per sq. ft. per 1″ thickness at a mean temperature of 60 degrees F. Not only does Q-T Ductliner provide sound absorption, but also thermal insulation, eliminating the need of thermal insulation to be applied on the outside of the duct.

Application

Mechanics have no difficulty in cutting and fitting Q-T Ductliner. It may be cut with a knife, and fastened mechanically with bolts or spot cemented with an approved acoustical cement.

SOUND ABSORPTION COEFFICIENTS

Frequency in Cycles per sec.	128	256	512	1024	2048	4000	N.R.C.	A.M.A. Test
Per cent absorption ½″ thick	.35	.25	.54	.75	.76	.66	.60	#289
Per cent absorption 1″ thick	.43	.37	.69	.78	.78	.70	.65	#290

Sizes: Q-T Ductliner is available in one standard size, 24″x36″ and in thicknesses of ½″ and 1″. Weight is approximately 1½ lb. per sq. ft. 1″ thick.

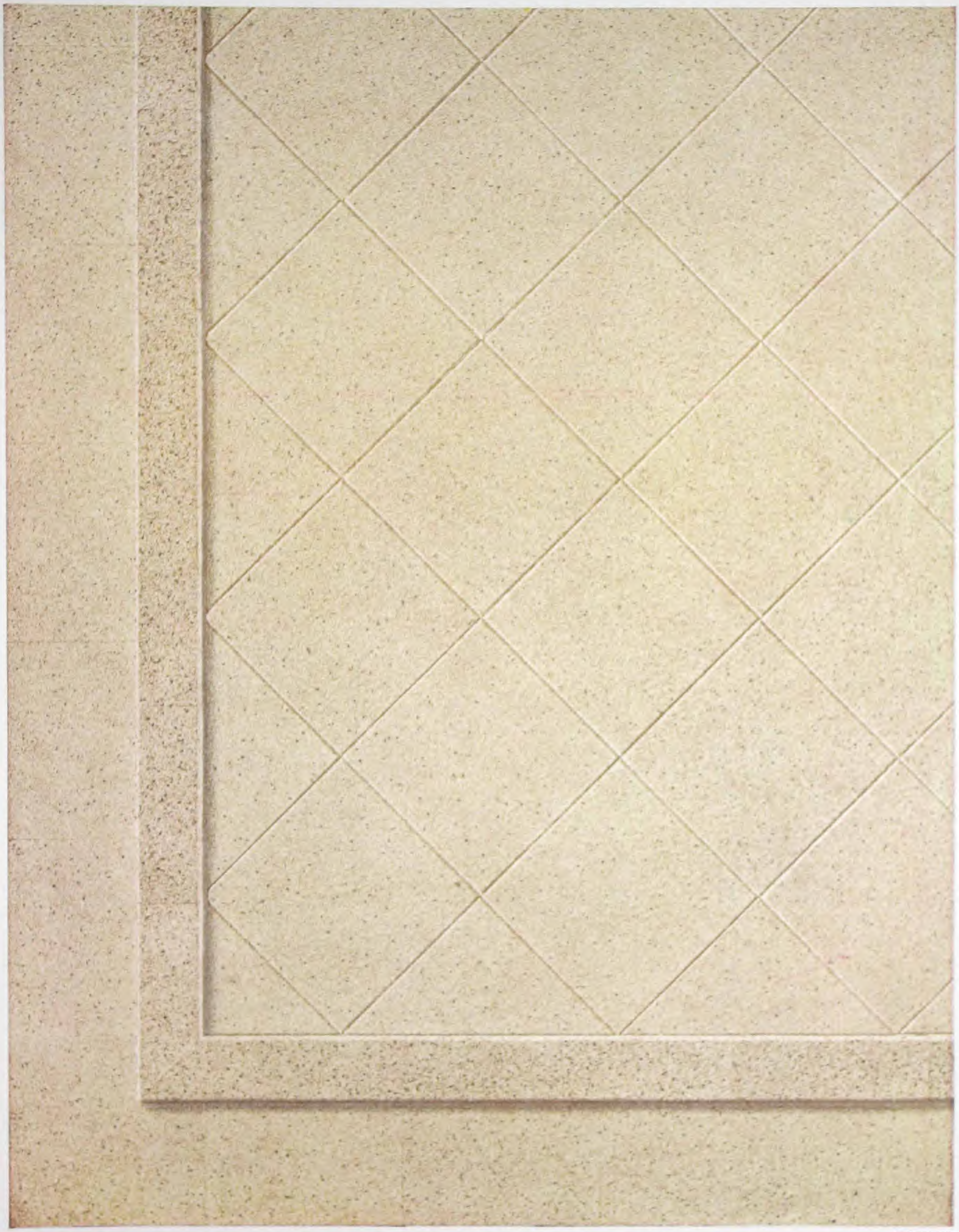
This Helpful Data Sheet Will Aid You in Checking All Requirements Of Your Acoustical Problems

SELECTING AN ACOUSTICAL MATERIAL—SHEET 1—

	ABSORPTION		MAINTENANCE			LIGHT REFLECTION		METHOD OF APPLICATION	PROBABLE LIFE				APPEARANCE	OTHER FUNCTIONS	COMBUSTIBILITY	FUTURE ALTERATIONS OR TRANSFER		FUTURE RESPONSIBILITY	
	Initial	After Painting	Cost of Painting	Cost of Washing	Cost of Cleaning	Initial	After Repainting	What method? What experience record?	Will material dust, settle, or peel?	Subject to attack by termites-vermin?	Subject to bodily contact or ball impact?	Subject to excessive humidities		Heat insulation? Interior finish? Decoration?	In considering fire risk, weigh method of application	Past history? Is product frequently changed?	Can material be salvaged for transfer? Estimated unit cost?	Material Manufacturer	Workmanship Contractor
RESTAURANTS																			
Dining rooms																			
Kitchens																			
Dishwashing rooms																			
CHURCHES																			
Auditorium																			
Foyer																			
THEATRES																			
Auditorium																			
Lobbies																			
RADIO STUDIOS																			
Studios																			
Reception and Public rooms																			
COURT HOUSES																			
Court-rooms & Council Chambers																			
Public rooms																			
HOTELS																			
Lobbies and Corridors																			
Convention and Ball rooms																			
Guest rooms																			
RESIDENCES																			
Living and Dining rooms																			
Kitchens and Pantries																			
Bath rooms																			
TRANSPORTATION TERMINALS																			
SHOOTING RANGES																			
BOWLING ALLEYS																			

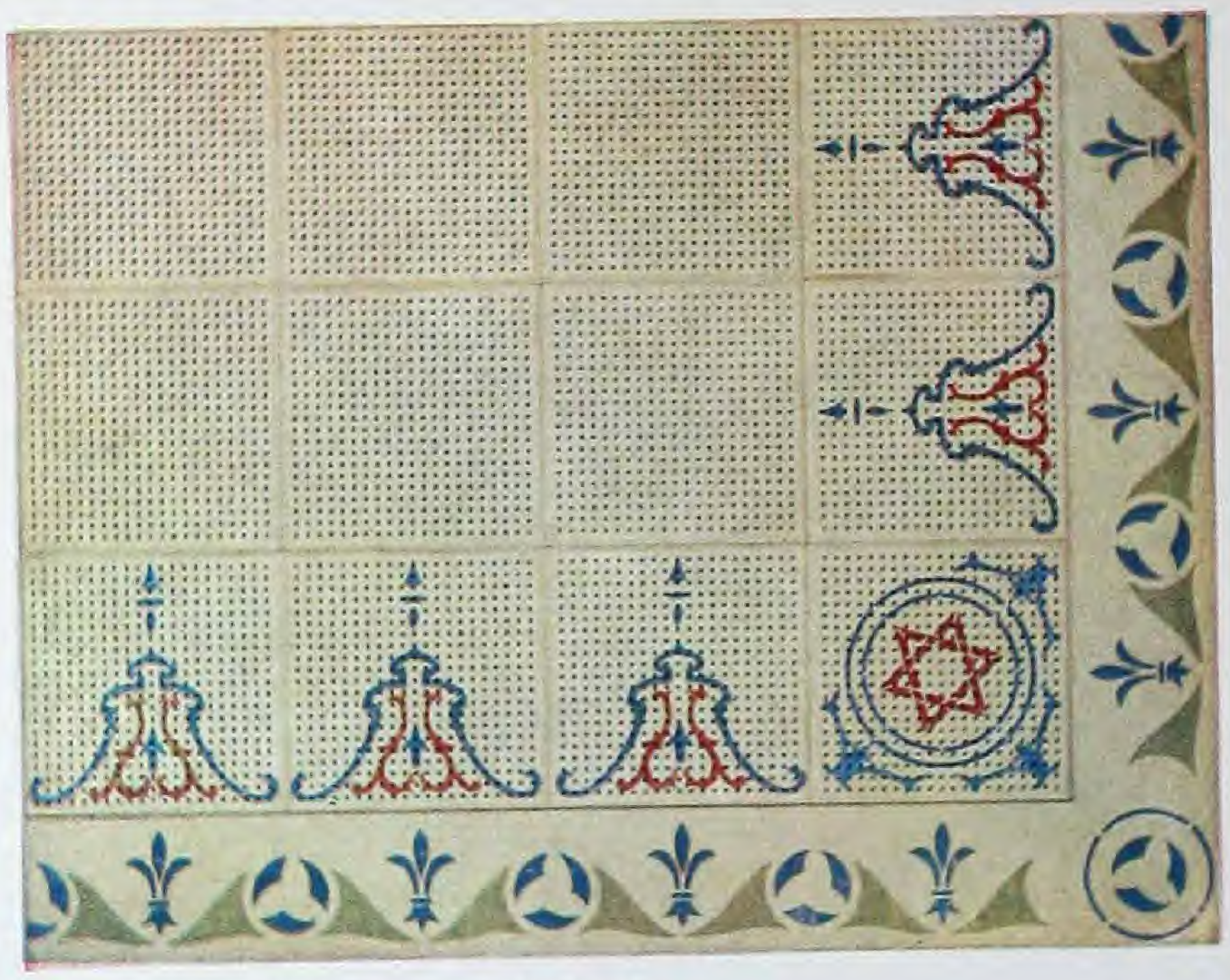
Whittier National Trust and Savings Bank—Whittier, California
Architect, William H. Harrison.—Acousti-Celotex.

Standard Calicel field with Tapestry coffers, photographed in natural color.

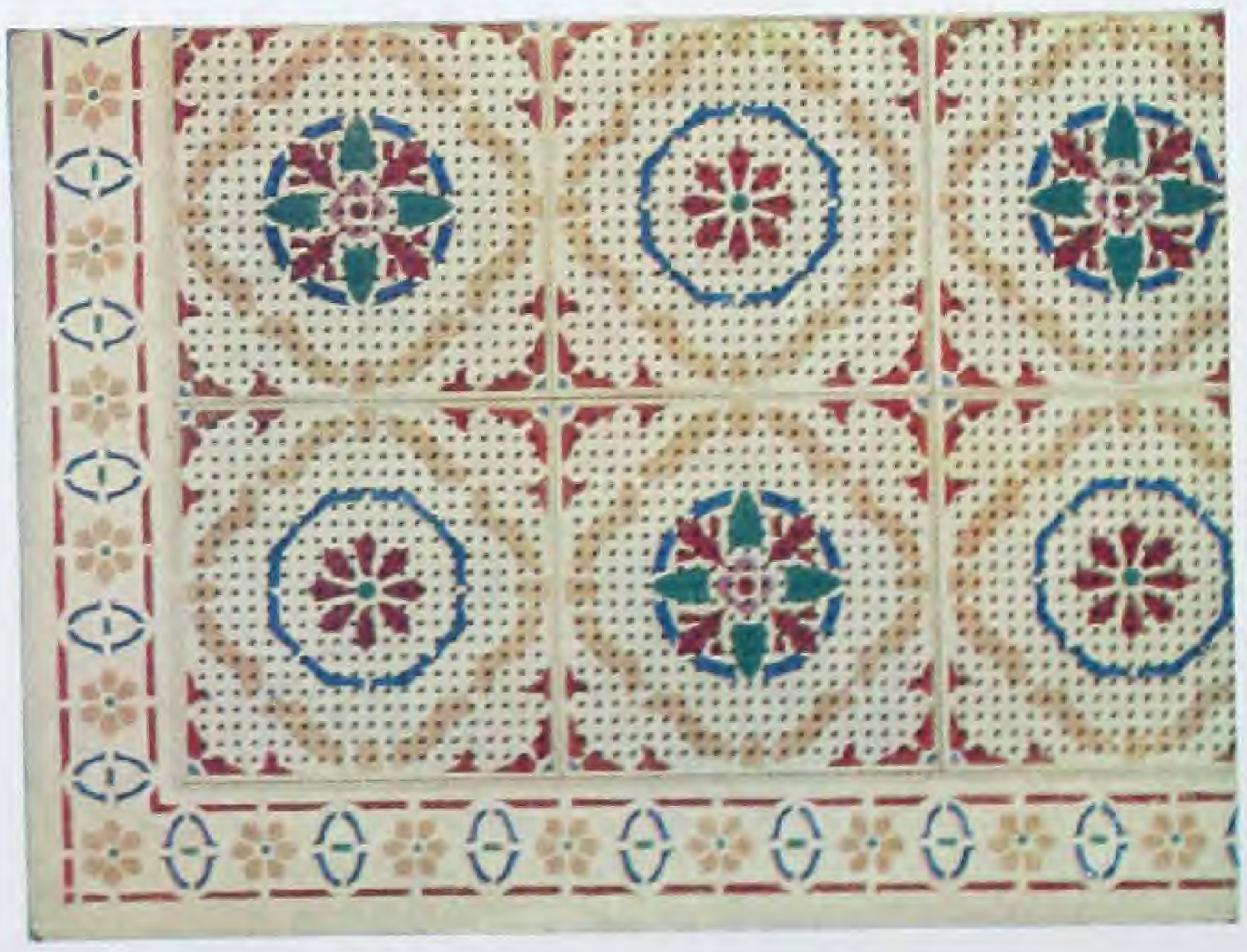


Standard Calicel field in diamond pattern, with Italian border, photographed in natural color.

DECORATED ACOUSTI-CELOTEX



SIX DECORATIVE ACOUSTI-CELOTEX DESIGNS IN COLOR
TAKEN FROM ACTUAL CEILING INSTALLATIONS.



Bank of Manhattan Trust Co., Bronx, New York—Acousti-Celotex—Architect—Morrell Smith

Wm. Neilson, Ltd., Toronto, Canada. Acousti-Celotex—Architects, Mathers & Haldenby

OFFICES

NOISE reduction is as essential to the efficient office as effective illumination and ventilation. The difference between noisy and reasonably quiet conditions may be expressed in terms of about 10% of the total output. Ten per cent of annual salaries represented in the average noisy office makes acoustical treatment, for anything but short-term occupancy, a profitable investment.

We may control noise, but we cannot control our biological reactions to it. Science proves the fallacy of thinking we "get used to noise"—we may not be aware of its effects upon us, but the effects are still present. And these effects are not merely imaginary, nor found in only a few nervous people. The effects are automatic, of a reflex nature, and are probably ineradicable. They have been developed through long centuries of evolution and originally served a useful purpose in warning our remote ancestors to get away from the danger signaled by the roar of a wild animal or the onrush of a landslide. Although useful at one time in mankind's early development, these involuntary and inevitable reactions to noise are now a definite handicap to human welfare.

Press Telegram—Office of Mr. Frick, Long Beach, Calif.
Acousti-Celotex—Architect, Wm. Horace Austin

Lane-Wells Co.—Mr. Wells' Office, Los Angeles, Calif.
Acousti-Celotex—Architect, Albert E. Hansen

Upjohn Chemical Co., Kalamazoo, Mich.—
Acousti-Celotex—Architects, Albert Kahn, Inc.

These benefits have been observed by users of acoustical treatment in noisy offices:

1. Increased volume of work in a given time.
2. Reduction in percentage of errors.
3. Less absences from work.
4. More efficient and economical use of the telephone and other mechanical equipment.
5. Elimination of partitions, resulting in fuller use of floor space and improved illumination and ventilation.
6. An improved atmosphere welcome to customers.
7. A pleasanter, happier disposition in the office force.

Rufus King High School, Milwaukee, Wisconsin—Calicel

SCHOOLS

THE harmful effects of noise are admirably and most capably discussed by a prominent physician and a famous psychologist in a booklet on Noise published by The Celotex Corporation and available on request.

Progressive educators have been among the first to recognize the value of acoustical treatment in schools.

"I am writing to congratulate you on the excellent job of acoustical ceiling treatment on the new University High School. . . . The contrast between this school and the other schools not so treated is very evident and is remarked upon by all visitors. The noise-subduing effect of the treatment in corridors and halls is most evident and we are highly pleased with the work," writes B. F. Pittenger, Dean of the School of Education, The University of Texas at Austin.

Brother Anthony, Superior of Morris Institute at Searcy, Arkansas comments, "We derive quite a little amusement from visitors and inspectors by whom we are frequently asked, 'why we do not allow the boys to be as noisy in the gym as in the adjoining playhalls.' Although they saw the boys run and romp as only boys can do with mouths wide open, the visitors felt that restrictions had been imposed until we explained to them the effect of the Acousti-Celotex on the ceiling."

"From our experience with the use of Acousti-Celotex in one of our elementary school auditoriums, as well as from observing the difference in the two rooms in the high school where Acousti-Celotex was installed a number of years ago," quoting E. J. Hummell, Super-

University of Minnesota, Room 101—Wesbrook Hall, Minneapolis, Minn.—Acousti-Celotex

Quarton School, Birmingham, Mich.—Acousti-Celotex
Architect: Frederick D. Madison

intendent of Schools for the Beverly Hills Unified School District, Beverly Hills, California, "we concluded that only by a complete installation in the new Beverly Hills High School could we have a thoroughly satisfactory and modern building from an acoustical standpoint. I had occasion a few days ago to check on the installation you are making for us, and wish to say that I am sure we are going to be delighted with the results of the installation which will give us excellent acoustics throughout the entire group of buildings."

And from Charles A. Smith, Kansas City Architect, "For a number of years I have been using acoustical treatment in the Auditoriums, Music and Expression rooms, Gymnasiums and Swimming Pool Rooms of all school buildings, wherever the funds available would allow of its use. The beneficial results more than justify the cost.

"Various materials and methods have been used by these installations most of which have been reasonably successful in absorbing sound waves and preventing reverberation. However, some of the materials used appeared to be of a flimsy nature and were lacking in permanency.

"Acousti-Celotex appealed to me from the first as being free from these objectionable features and as having a pleasing appearance and being susceptible of decorative treatment without affecting its efficiency.

"I have used Acousti-Celotex treatment in twenty-five school buildings in Kansas City, Missouri, and in many other buildings in the surrounding territory, with uniformly satisfactory results. It is included in the plans and specifications for school buildings now being prepared in my office."

"The Irvington School has Acousti-Celotex ceilings throughout and the difference in quietness between that building and all other school buildings of the city, is amazing. There is a peace and a relaxed atmosphere which not only simplifies the task of administration, but also improves the disposition and temperament of teachers and pupils. It is one of the greatest agencies for mental hygiene that can be introduced into the schoolhouse.

H. M. Barr, *Director Research Dept.*
Portland, Oregon, Public Schools."

Rufus King High School Auditorium, Milwaukee, Wisconsin—Calistone
Architect: Guy E. Wiley, Milwaukee School Board

Passavant Hospital, Chicago, Illinois—Acousti-Celotex

Santa Fe Hospital Kitchen, Los Angeles, Calif., Acousti-Celotex—Architect, H. L. Gilman

HOSPITALS

FROM the days of Galen and Hippocrates physicians have insisted upon quiet surroundings for their patients; the simple fact that health returned more quickly in a quieter room was reason enough for insisting upon freedom from noise in the sick room.

The one great need of some patients is rest and peace. Medicines will do them very little good, but the recuperative powers of nature, if they are allowed to have their way, will help them and cure them Give those powers a chance, by keeping everything in the hospital as quiet and as peaceful as possible.

Acousti-Celotex users say:

"The results are really beyond our expectations. The installation of Acousti-Celotex in the Maternity Wing of our Hospital has completely isolated this department. The babies' cries which were so annoying to mothers cannot now be heard in the adjoining rooms."

"Our building is constructed of brick and hollow tile with terrazzo floors, and noise has been one of our biggest problems since it was opened. The halls and corridors have been so noisy that our patients complained continuously. In 1929 we opened up the first floor for children and at that time realized that we would have to do something if we were to keep children in the building and not have continuous complaints from our patients. You treated the ceilings of two halls and our main diet kitchen with Acousti-Celotex and from that time we have kept the children on this floor with no complaint from patients in other wings of the building. This material has proven very satisfactory."

"Over a year ago we installed Acousti-Celotex in the corridors of our hospital, and our officials, as well as the many patients that are continually passing through, have been exceptionally well pleased with this improvement."

We asked M. T. MacEachern, M.D., C.M., Director of Hospital Activities of the American College of Surgeons, about the sanitation of Acousti-Celotex in hospitals. He replied:

"Placing the material on the ceiling where it is out of the reach of patients and workers and providing it with an enameled surface which can be washed, is undoubtedly a safe practice. The adequate fumigation of the room at the necessary intervals will take care of properly disinfecting the sound absorbing material along with the other articles and wall surfaces in the room. The perforations in Acousti-Celotex do not place it at a disadvantage with other sound absorbing materials, and if the foregoing conditions are carried out, its use in hospitals is to be recommended."

Acoustic-Celotex is available with a factory-applied, washable enamel finish. The installation of Acousti-Celotex is not a noisy process.

Benedictine Chapel, Mundelein, Illinois—Calicel—Architect, Joseph W. McCarthy

CHURCHES

The successful and effective preservation of both speech and music requires good acoustics. For this reason Celotex acoustical products are used extensively in church auditoriums, church parlors, and meeting halls.

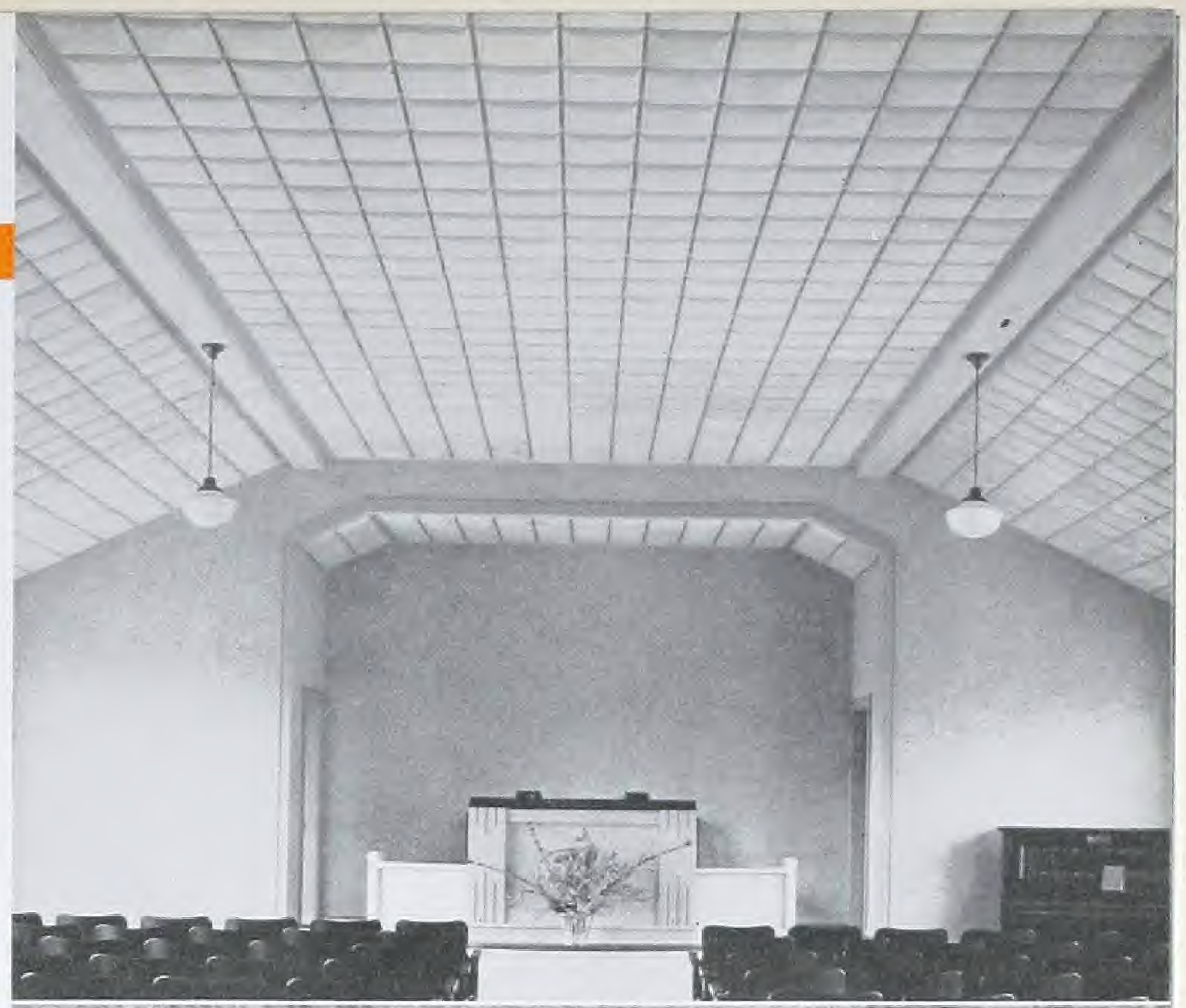
New churches built without acoustical treatment suffer from poor hearing conditions as well as old churches which have been built for some years. The science of correcting poor hearing facilities is now so advanced that this work may be done without in any way marring the beauty of established architectural design, and color. Finishes to harmonize with established architectural designs are always available.

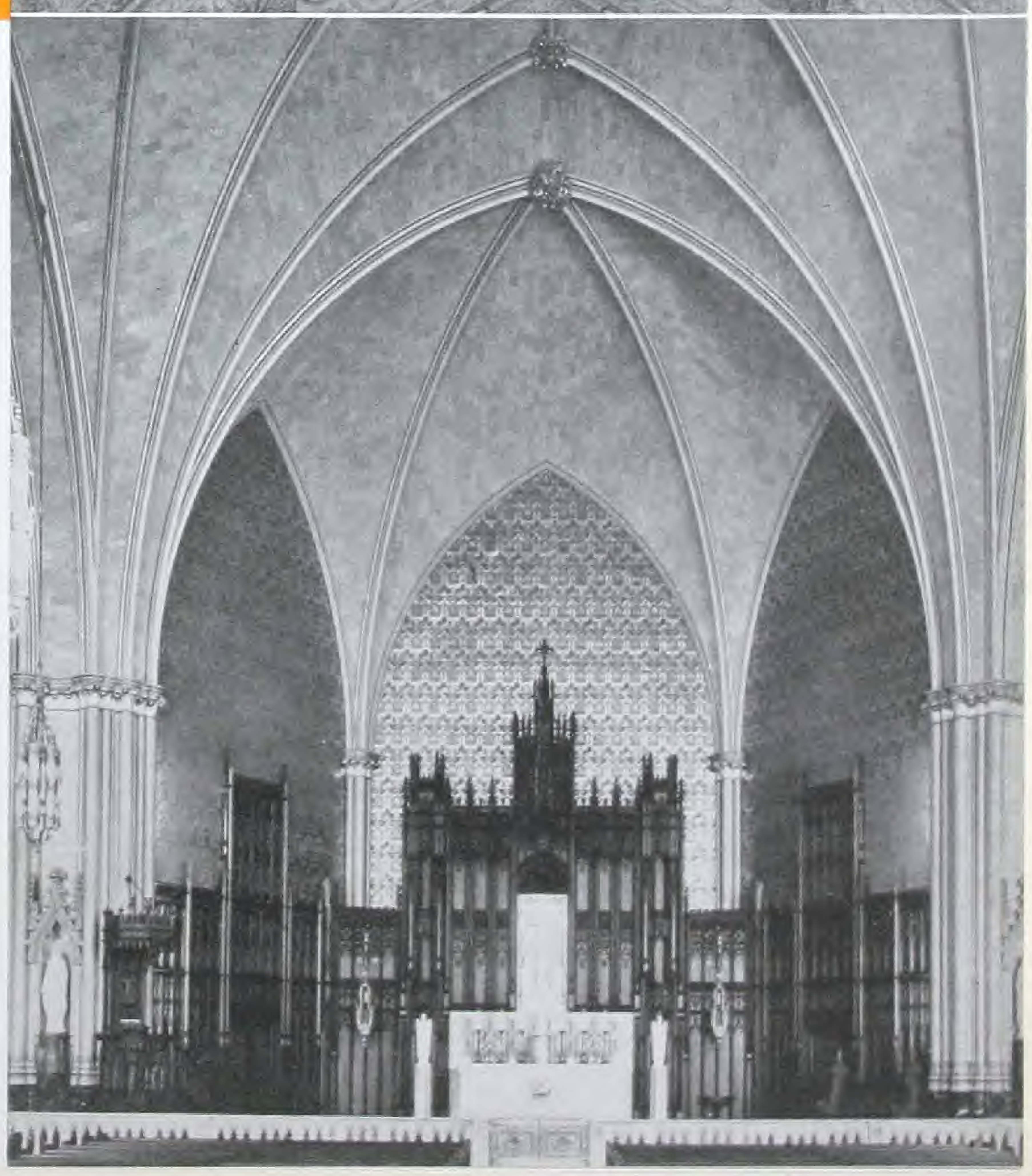
Upper right: *Church of Christ Scientist, Fayetteville, Arkansas—Vibrafram (formerly Heerwagen Tile)*

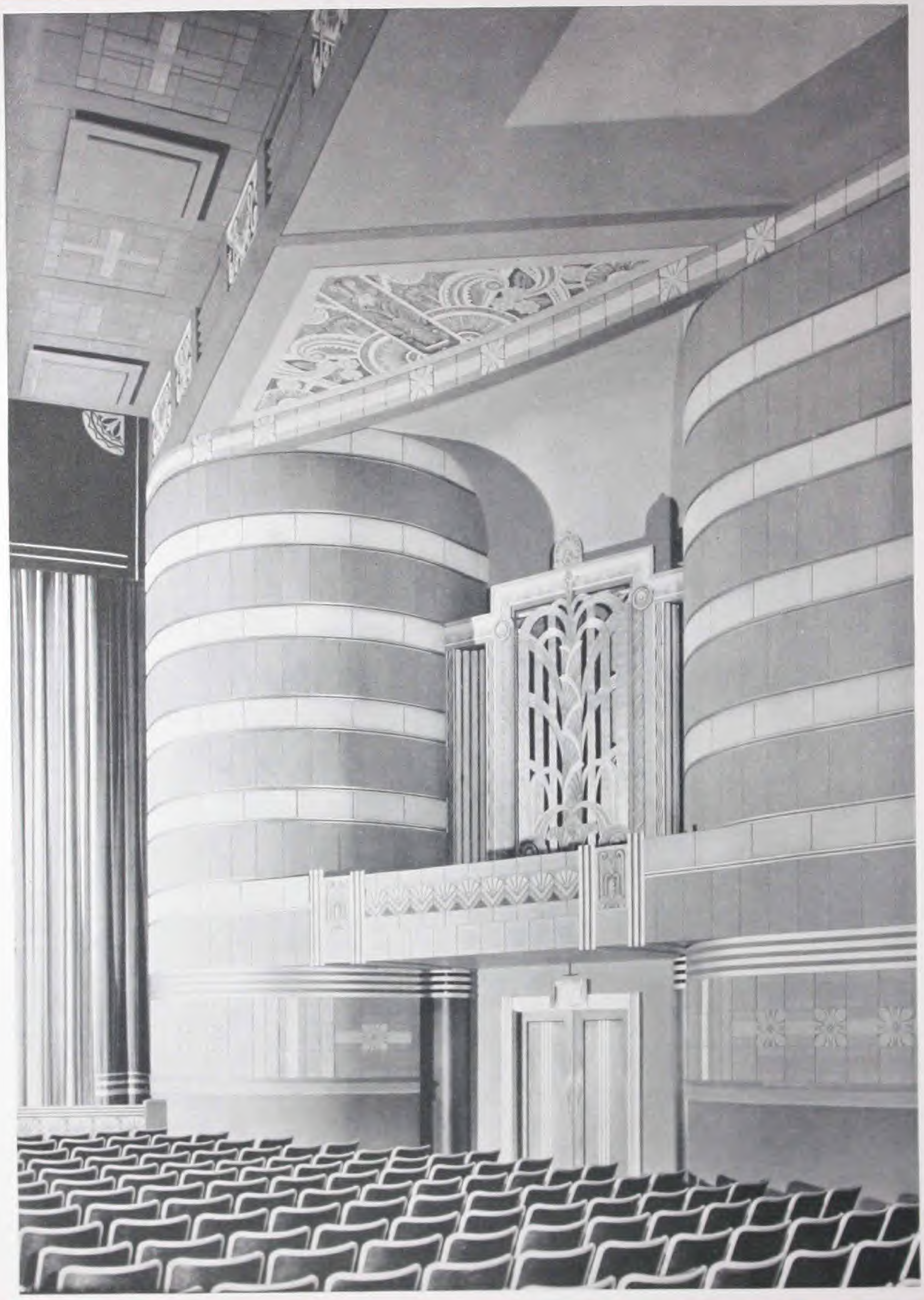
Right: *Church of the Blessed Sacrament, Springfield, Illinois —Acousti-Celotex—Architects, Aschauer & Waggoner*

Lower right: *St. Sabina's Catholic Church, Chicago, Illinois —Calicel—Architect, Joseph McCarthy*

Below: *Seminary of St. Thomas Chapel, Denver, Colorado Acousti-Celotex—Architect J. B. Benedict*

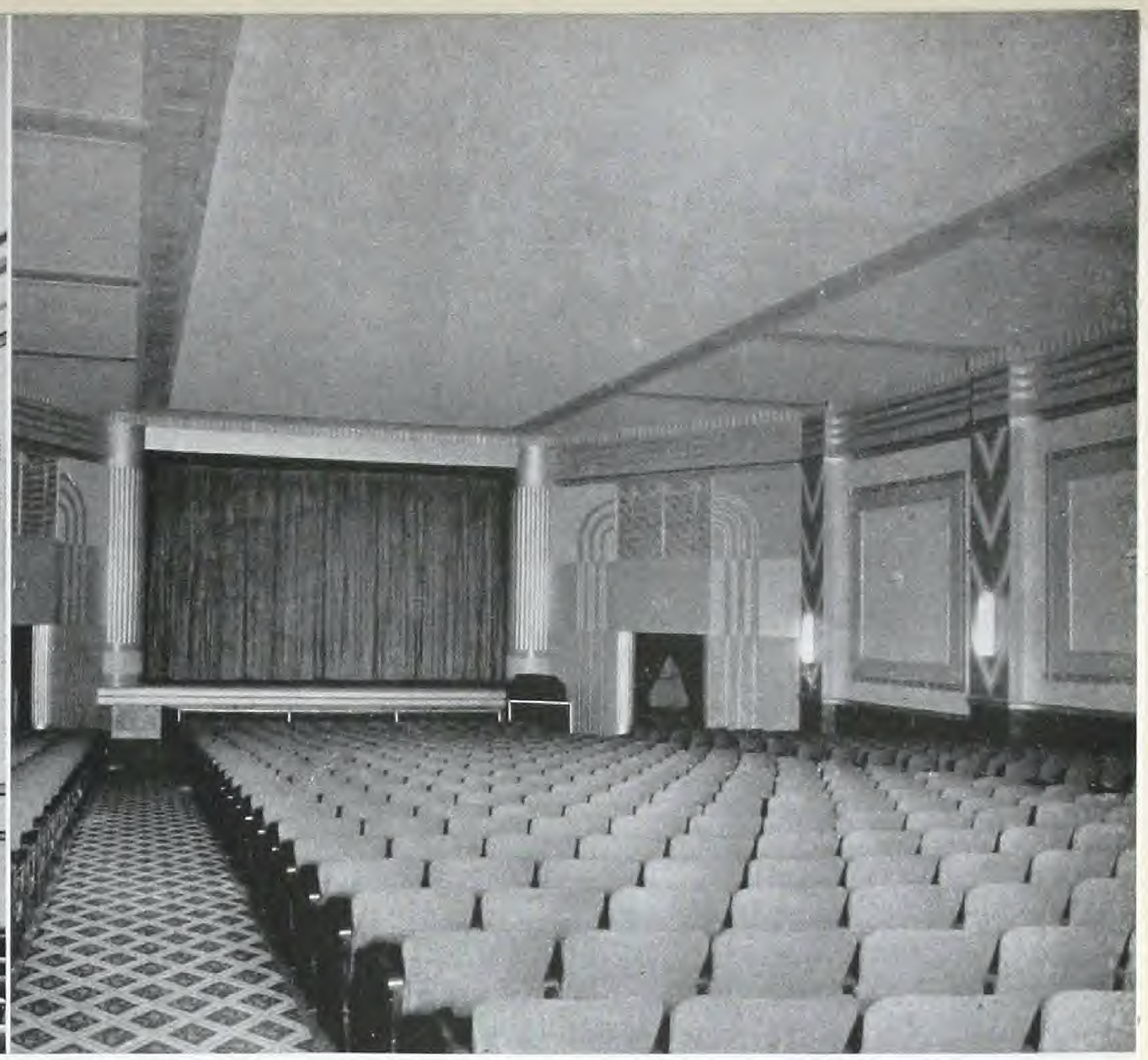






Ambassador Theatre, Baltimore, Md., Acousti-Celotex—Architect, John J. Zink

Empire Theatre, Quebec, Canada—Vibrafram (formerly Heerwagen Tile)



Monte Vista Theatre, Cincinnati, Ohio—Calicel

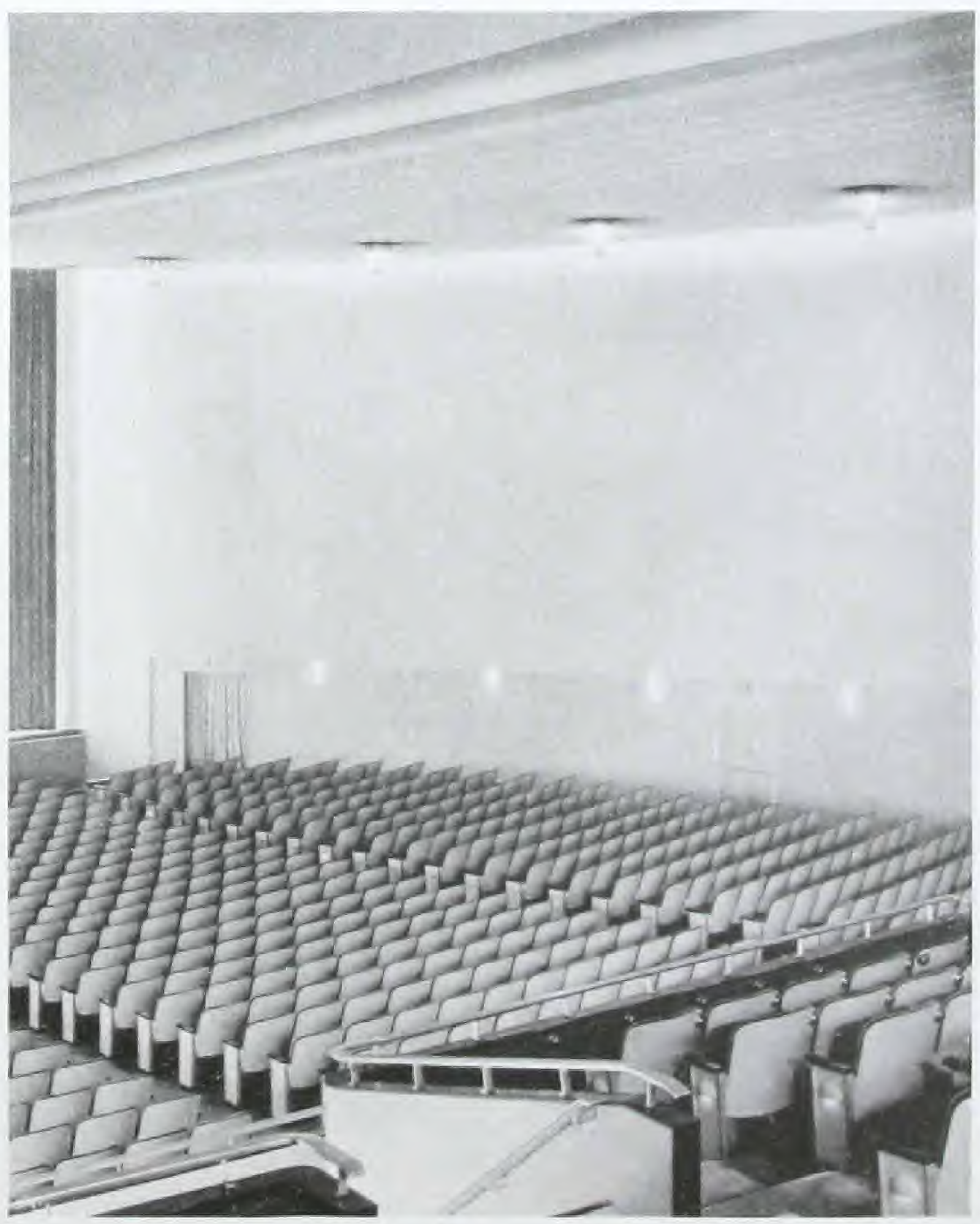
THEATRES

IN acoustical treatment, alert and aggressive theatre owners have a potentially powerful merchandising idea. Few theatres have taken advantage of developments in the science of acoustical correction and the public's enjoyment of sound pictures is daily marred by faulty hearing conditions.

Many houses have been driven to the use of some sound-absorbing material, and have resorted to the use, often times haphazard, of felts and fabrics, insulation board, etc. A degree of relief has been observed, and the owner has rested content in the belief that his house has been acoustically corrected. Only comparison with a house in which acoustical perfection has been approached can fully convey the sales promotion potentiality which can be capitalized in scientific acoustical correction.

Improvements in sound projection equipment, extending the range of faithful reproduction, provide theatre owners with a means of attracting larger attendance only if the acoustics of the house permit their undistorted enjoyment. By the installation of Celotex acoustical products, applied by Celotex acoustical engineers, these results are obtained.

Beverly Theatre, Chicago, Illinois—Absorbex—Architect, Ronald F. Perry



RESTAURANTS

THE frequency with which the remark "Let's go to a quiet place" is heard is ample testimony to the value of acoustical treatment to the progressive restaurateur. Whether this is due to a realization that common noise intensities retard the secretion of gastric juices and interfere with the digestive contractions of the stomach, or to the futility of trying to engage in pleasant conversation in a noisy dining room, is beside the point.

Here are some Acousti-Celotex testimonials:

"After a very satisfactory experience with Acousti-Celotex in the dining-room, we had it installed in our kitchen. Our guests immediately noticed a decided improvement and many favorable comments were heard."

"When you told me several months ago that you could eliminate the noise in our cafe I thought you were joking—Now that you have installed Acousti-Celotex on the ceiling I want you to know that the results are even better than we had anticipated. The noise and clatter has been eliminated and in its place we now have an atmosphere of quiet and restfulness. We also find that many of our patrons who refused to eat here on account of the noise are returning. In addition, our employees find that they are considerably less tired at the end of their day's work now than they were before."

"Our place was extremely noisy, especially back of our serving counters and in the dishwashing room. Your treatment has deadened the excessive clatter of dishes, trays, etc., to a marked degree of success."

"The installation of Acousti-Celotex on the walls and ceiling in our dishwashing room has eliminated the penetration of noise into surrounding dining rooms and solved one of the most difficult problems we had to face."

"We know of no expenditure in our entire experience which has given us any more satisfaction than this one."

Left: *Waldorf-Astoria Hotel, Men's Bar, New York City—Acousti-Celotex*

Upper Right: *University of Minnesota, Minnesota Union Cafeteria, Minneapolis, Minn.—Acousti-Celotex*

Lower Right: *Ira Wilson Dairy Co., Detroit, Michigan Acousti-Celotex—Architect, Richard H. Marr.*

Calhoun College, Yale University, New Haven, Conn.—Absorbex—Architect John Russell Pope.

Fox Department Store, Hartford, Conn.—Acousti-Celotex

RETAIL STORES

THERE is a growing use of acoustical treatment for noise quieting in retail stores. These benefits have proved the value of the investment:

1. Creates an inviting and pleasant store atmosphere;
2. Lessens shoppers' fatigue;
3. Lessens clerks' fatigue and reduces nerve strain, enabling them to keep alert and pleasant;
4. Makes conversation easier;
5. Facilitates handling of purchases.

On next page above:—*Tra Waiting Room, N. Central R. R., Syracus N. Y.—Calicel Acoustic Castone.*

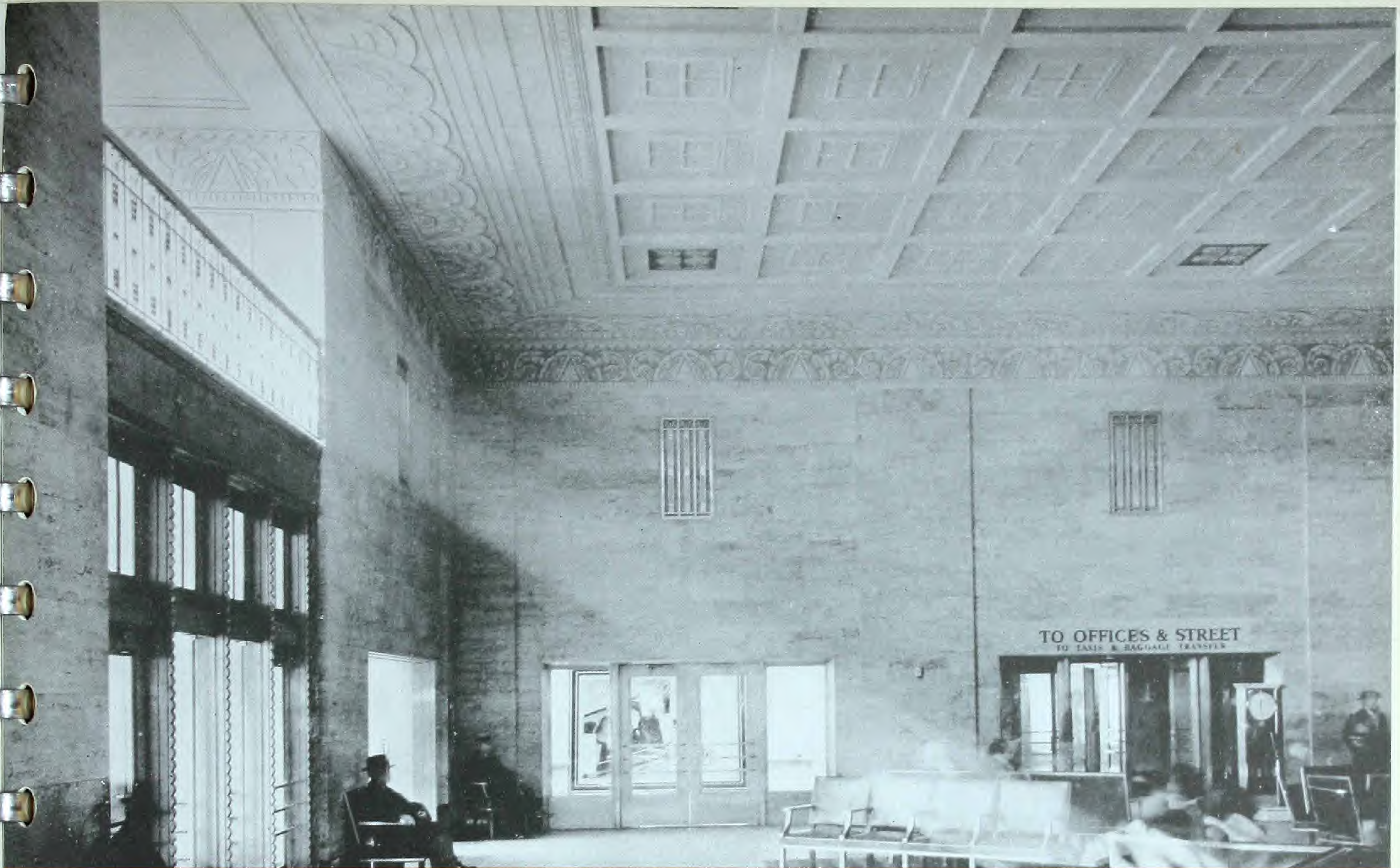
Below: *County Municipal Cou room, Milwaukee Publ Safety Building — Aco sti-Celotex — Architec Albert Randolph Ro*

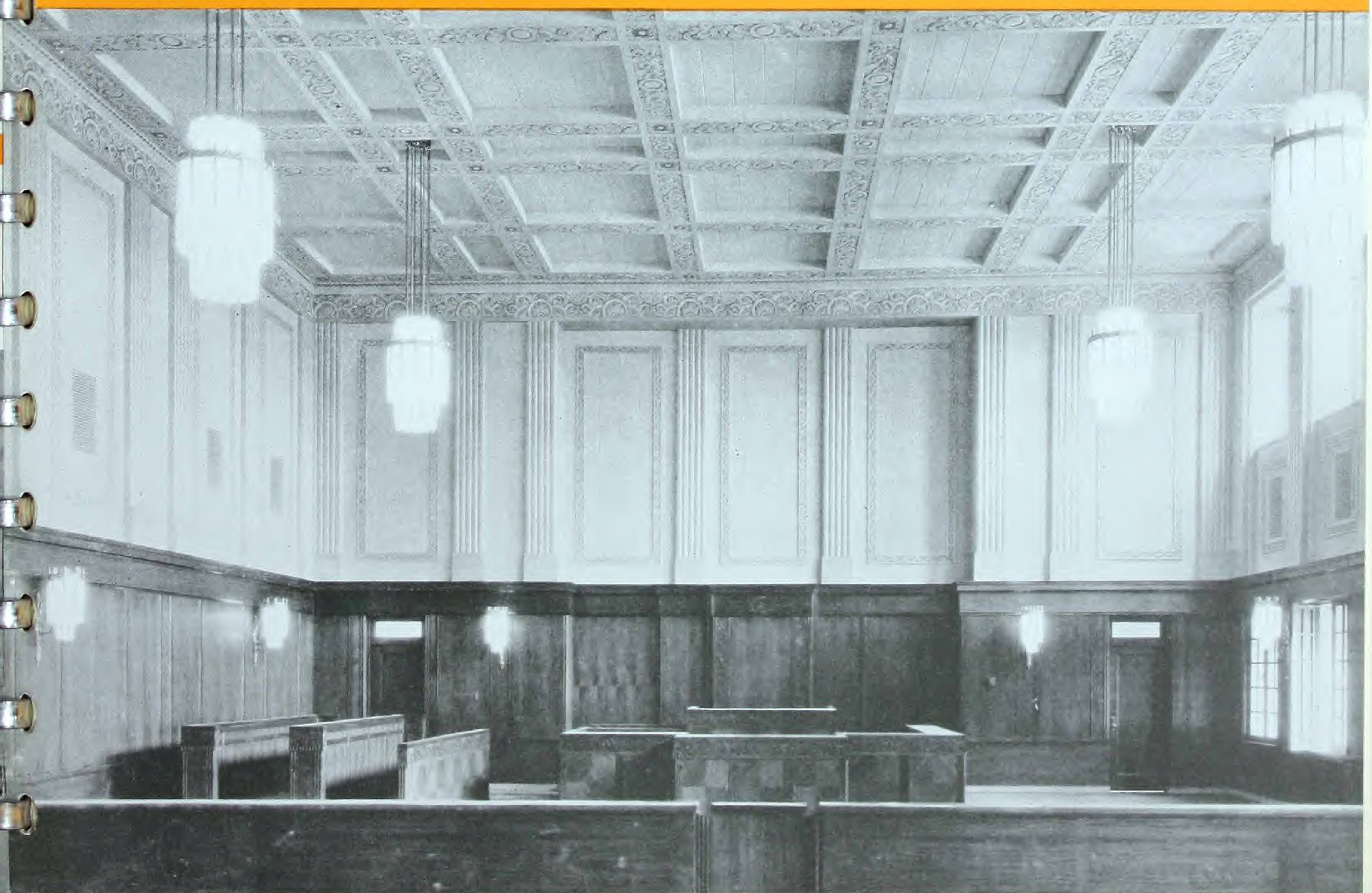
Royal Ontario Museum, Toronto, Ont., Canada —Acousti-Celotex

PUBLIC BUILDINGS

Pennsylvania R. R. Station Waiting Room, Newark, New Jersey—Calicel—Calistone —Architects McKim, Meade & White

Bowling Alleys in East Liberty Presbyterian Church, Pittsburgh, Pa. —Absorbex—Architects, Cram and Ferguson


TO OFFICES & STREET



Jay Paley Residence (Interior), 1060 Brooklawn Drive, West Los Angeles, Calif. Acousti-Celotex—Architect, Paul R. Williams

Jay Paley Residence (Exterior)

RESIDENCES

THE purpose of acoustical treatment in residences is not to be confused with stopping the transmission of sound through walls, floors, and ceilings. The problem of stopping the transmission of sound, whether it be air-borne or impact (such as the sound of footsteps heard in the room below), is a special one involving individual analysis and recommendation. The mere application of sound-absorbing material on walls or ceilings will not solve problems of this kind.

Where noisy reverberant room conditions exist, however, acoustical treatment provides welcome relief. Installations of this kind include living rooms, dining rooms, kitchens and pantries, bathrooms, recreation rooms, nurseries and libraries.

Celotex Acoustical Products

THE demand for acoustical materials has extended into so many different fields that obviously no single product can ideally satisfy all needs. It is the policy of The Celotex Corporation to provide a variety of acoustical products suited to growing market needs, maintaining the same standards of dependable quality that have won for Acousti-Celotex the pre-eminence it enjoys.

ACOUSTI-CELOTEX
AN ACOUSTICAL PRODUCT BY
CELOTEX

This registered trade-mark identifies a Celotex Acoustical Product whose most distinguishing characteristic is its perforations. These perforations (patented) are of definite diameter, depth and spacing.

Cross Sections of Acousti-Celotex

Because of this patented feature, Acousti-Celotex can be repeatedly painted, with any standard paint, without impairing its sound-absorbing efficiency. Paint does not seal the openings to the tubular channels through which the sound waves enter the porous block and are absorbed.

In terms of footage, the greatest sale of acoustical material today is in the noise-quieting field — offices, hospitals, schoolrooms, restaurants — where renewable light reflection and consequently *paintability* is of paramount importance.

Maintenance

Acousti-Celotex can be repeatedly painted with any standard paint without impairing its sound-absorbing efficiency. It may also be washed to renew light reflection values until painting is necessary.

ACOUSTI-CELOTEX

C-Series

C-Series Acousti-Celotex is made of tough cane fibres called bagasse. In the minute interstices between the fibres, sound is dissipated by friction.

The most important technical advantages of bagasse fibre are purity, resistance to decay, length, strength,

springiness, bulk, and the sawtooth character of the fibre. Owing to the deficiency in nitrogen and mineral salts, the bagasse is much more resistant to decay than other vegetable fibres.

Because acoustical material is usually applied on ceilings it is desirable to combine lightness in weight with structural strength. Manufacturing methods may aid in achieving the desired results, but in bagasse fibres we have the peculiar advantages of length, strength, toughness and durability, resiliency, air-spaces within fibre particles and serrated sawtooth surfaces which will permit proper felting.

Conductivity

The conductivity of a material is a measure of its heat resistance or insulating value and is the number of heat units (Btu) that will pass through one square foot of the material in one hour for each degree difference in temperature between the two sides of a one inch thickness. The lower the conductivity of a material the greater its heat resistance for a given thickness.

The conductivity of C-Series Acousti-Celotex is 0.33 Btu per hour per square foot per degree Fahrenheit per inch thickness.

Moisture Resistance

C-Series Acousti-Celotex tile are integrally waterproofed during manufacture by means of a chemical treatment. The practical value of this treatment has been borne out by thousands of installations in all parts of the world, including severe tests in flooded areas.

However, C-Series Acousti-Celotex is not recommended for use in rooms where conditions of continual excessive humidity exist.

Ferox Process

The Ferox Process (patented), now being used in the manufacture of C-Series Acousti-Celotex, is a method whereby the individual fibres, in their wet state and before formation into a board, are coated with a chemical complex which is toxic to fungi, termites and other cellulose destroying organisms. This chemical complex is insoluble in water, non-volatile, odorless, permanent, and in no way alters the physical properties or utility of the finished product. The Ferox processed Celotex product presents no hazard to humans or domestic animals, but provides valuable protection against termites and dry rot.

Absorption Coefficients and Specifications of Test Samples

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Types of Mounting
1. Cemented to plaster board. Considered equivalent to cementing to plaster or concrete ceiling.
2. Nailed to 1" x 2" wood furring 12" o.c. unless otherwise indicated.
9. Attached to special metal supports mounted on 2" x 2" wood furring.

Material	Thickness	Mounting (Described above)	Coefficients 128	256	512	1024	2048	*Noise Reduction Coefficient	Unit Size Tested	Wt. (lbs.) sq. ft.	Surface	Test No.
CANE TILE												
Acousti-Celotex, Type C1	½"	1	.24	.27	.48	.57	.59	.50	12"x12"	.84	Painted by mfgr. with oil-base paint. Perforated 441 holes per sq. ft. 3/16" diam. 3/8" deep.	134
Acousti-Celotex, Type C1	½"	2	.36	.58	.51	.52	.62	.55	12"x12"	.84	Same as above.	151
Acousti-Celotex, Type C2	⅝"	1	.19	.20	.69	.85	.65	.60	12"x12"	.97	Painted same as above. Perforated same as above ½" deep.	136
Acousti-Celotex, Type C2	⅝"	2	.40	.59	.68	.81	.66	.70	12"x12"	.97	Same as above.	152
Acousti-Celotex, Type C3	13/16"	1	.25	.27	.76	.88	.60	.65	12"x12"	1.03	Painted same as above. Perforated same as above 11/16" deep.	137
Acousti-Celotex, Type C4	1¼"	1	.37	.43	.98	.79	.57	.70	12"x12"	1.50	Painted same as above. Perforated same as above 1 1/16" deep.	138
Acousti-Celotex, Type C4	1¼"	2	.35	.60	.98	.80	.54	.75	12"x12"	1.54	Same as above.	239
Acousti-Celotex, Type C5	13/16"	1	.14	.35	.63	.83	.90	.70	12"x12"	.95	Unpainted. Perforated 441 holes per sq. ft. ¼" diam. ⅝" deep.	3
Acousti-Celotex, Type C6	1¼"	1	.19	.41	.91	.92	.92	.80	12"x12"	1.37	Unpainted. Perforated same as above. 1" deep.	4
Acousti-Celotex, Type C7	1"	9	.37	.50	.69	.84	.77	.70	12"x24"	1.47	Painted by mfgr. with oil-base paint. Perforated 441 holes per sq. ft. 3/16" diam., ⅞" deep.	271

Acousti-Celotex, Type C8—Identical with Type C7 except as to size, being available only in 24" x 48" units. Where nailed to wood strips or joints, test values shown for type C7 may safely be assumed.

*The noise reduction coefficient is the average of the coefficients at frequencies from 256 to 2048 cycles inclusive, given to the nearest 5%. This average coefficient is recommended for use in comparing materials for noise quieting purposes in offices, hospitals, banks, corridors, etc.

For auditorium treatment, attention should be directed to the coefficients at 512 cycles and other frequencies as explained elsewhere.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

Rodent and Vermin Resistance

C-Series Acousti-Celotex contains no food for rats, mice or other rodents or vermin. Rodents will only attack it when food or water on the opposite side attracts them, in which case they may gnaw a hole through the material as they would through plaster, wood or even concrete. When this is done it will be noted that the fibres are left lying at the hole and are not eaten.

Fire Resistance

While it is not claimed that C-Series Acousti-Celotex is "fireproof" it does stand up well in actual service and in several respects may act as a fire retardent.

The seriousness of any fire depends primarily upon three factors, (1) the amount of combustible materials, (2) the rate at which these materials burn and (3) the effectiveness with which fire-stop partitions function. Building materials should contribute as little combustible gas as possible, and if they burn it is highly desirable that they burn slowly so as to give as much time as possible in which to extinguish the fire.

C-Series Acousti-Celotex is a valuable building material when viewed from each of these aspects because:

1. It does not flame readily as does wood, because it does not contain pitches or rosins, which under the influence of the temperature of combustion, may generate inflammable gases that accelerate the fire to the point where explosions result. C-Series tile burn or smolder at a more or less uniform rate.
2. As this material has a high heat insulating value it retards the passage of the heat of the fire to combustible matter beyond. There is, therefore, a tendency to confine the fire to the room in which it originates and to hold the fire until proper steps can be taken to put it out.
3. It is usually applied against a solid incombustible backing without open joints or cracks through which a flame can pass and ignite inflammable material beyond.

Resistance to Impact and Abrasion

Because of its toughness and resiliency, C-Series Acousti-Celotex is successfully used in gymnasiums where subjected to the impact of indoor baseballs, basketballs, etc. In such locations the thinner types should not be applied on furring strips unless the furring strips are set flush with the plaster. Where subject to body contact, such as wainscot areas, the VHR finished Acousti-Celotex provides a hard, durable wearing surface.

Sizes

Standard sizes are 6″ x 12″, 12″ x 12″, 12″ x 24″. Also available, at additional cost, in 6″ x 18″, 6″ x 24″, 6″ x 36″, 24″ x 24″, 24″ x 48″.

An 1/8″ bevel on all four sides of the tile face is standard. Bevels can be omitted, or changed at added expense if desired.

A continuous, unbroken treatment can be obtained, with perforations equi-distant from each other in the entire treated area, by the use of special trimmed-edge tile.

Finishes

(1) Unless otherwise specified, C-Series tile are furnished with a standard ivory coating rolled into the surface, (RI finish).

(2) RI plus flat white or cream paint, (Standard Paint finish).

(3) VHR (Varnish hot rolled)—an extremely hard finish suitable for the application of enamel as well as other standard paints. The VHR finish in itself is a dark brown color.

(4) VHR plus flat white or cream white paint (VHR Standard Paint finish).

(5) VHR plus DeLuxe flat white or cream white paint (VHR DeLuxe finish).

(6) VHR plus one undercoat and two finish coats of white or cream-white enamel in gloss or semi-gloss (VHR Enamel finish).

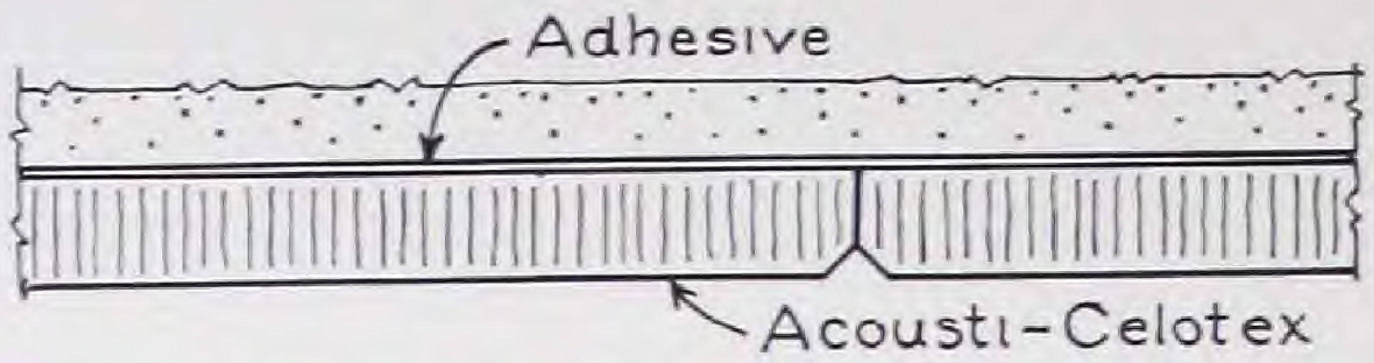
Light Reflection

Light reflection factors by authority of Curtis Lighting, Inc.

Cane Tile	Diameter of Perforations	
Finish	1/4″	3/16″
Natural	.29	.31
R I (Rolled Ivory)	.48	.56
Standard Paint Finish, flat white	.71	.74
Standard Paint Finish, cream white		.72
VHR Standard Paint Finish, flat white	.71	.76
VHR Standard Paint Finish, cream white		.74
VHR DeLuxe Finish, flat white	.71	.76
VHR DeLuxe Finish, cream white		.74
VHR Enamel Finish, white	.69	.74
VHR Enamel Finish, cream white		.73

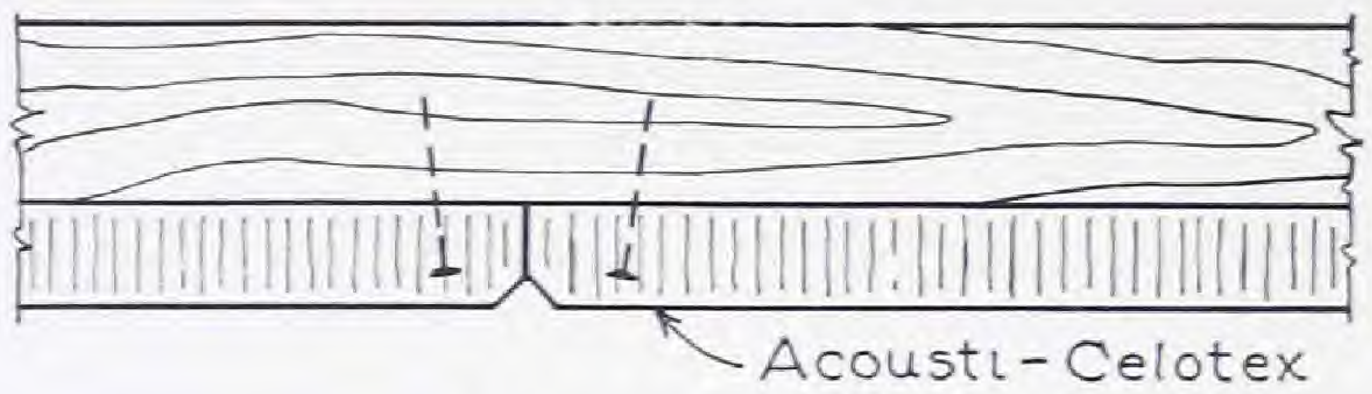
Construction Details

ACOUSTI-CELOTEX — CANE TILE



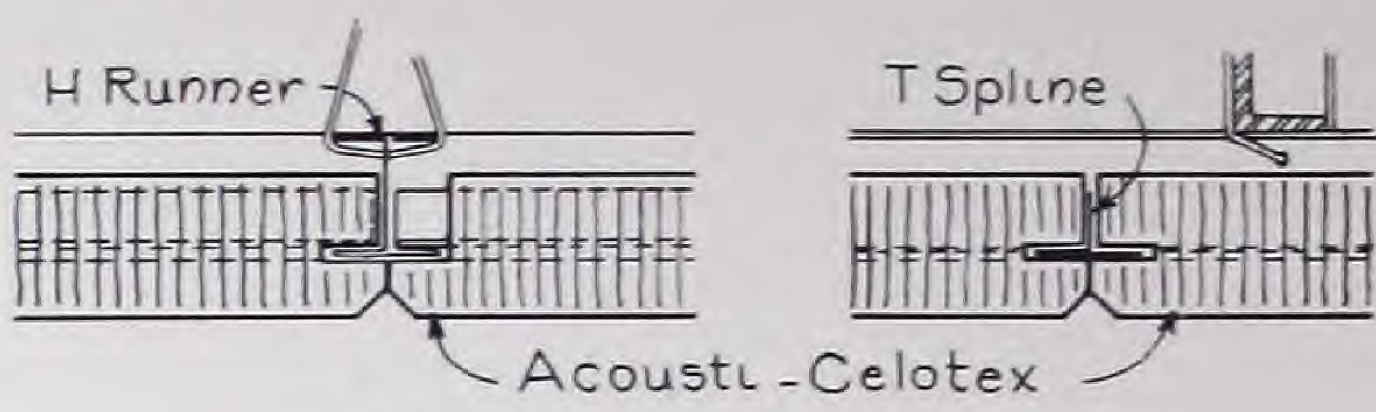
PLASTER OR CONCRETE CEILING

On plaster ceilings Acousti-Celotex is usually cemented (using an approved adhesive) and nailed directly to the plaster. If desired, Acousti-Celotex may be applied with a heavy bodied adhesive alone to the plaster or flat concrete surfaces, provided the installation is made by experienced workmen exercising necessary precautions.



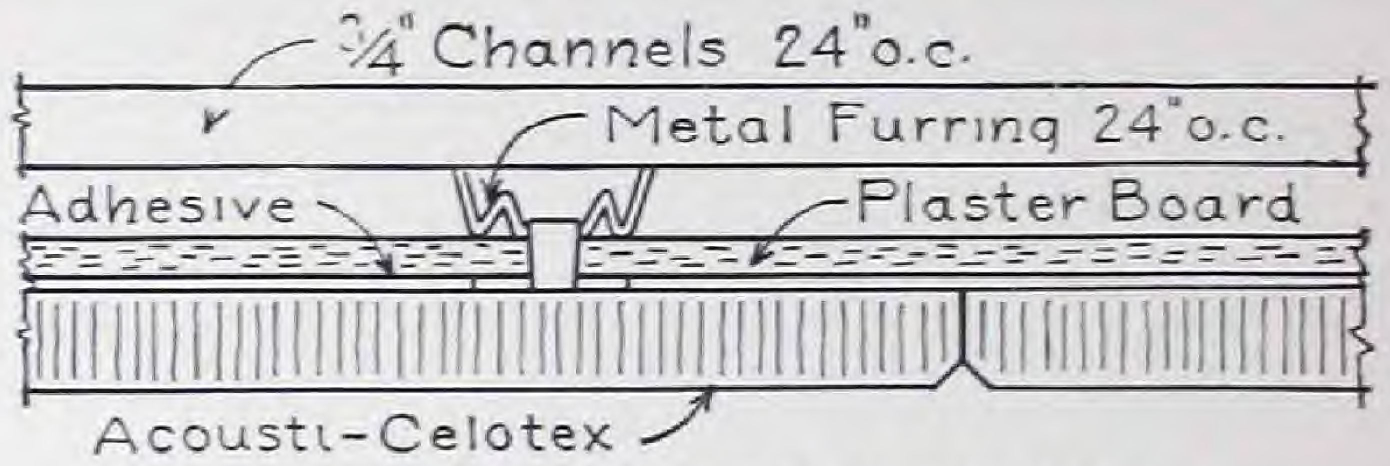
WOOD DECK

On ceilings of wood, as in churches or gymnasiums having an exposed wood roof deck, the Acousti-Celotex is nailed directly to the deck.



METAL SUSPENSION

Where it is desired to use Acousti-Celotex as the suspended ceiling by itself, the tiles are supported by metal members fastened to suspended metal furring, as shown above. Details of this type of construction are available on request.

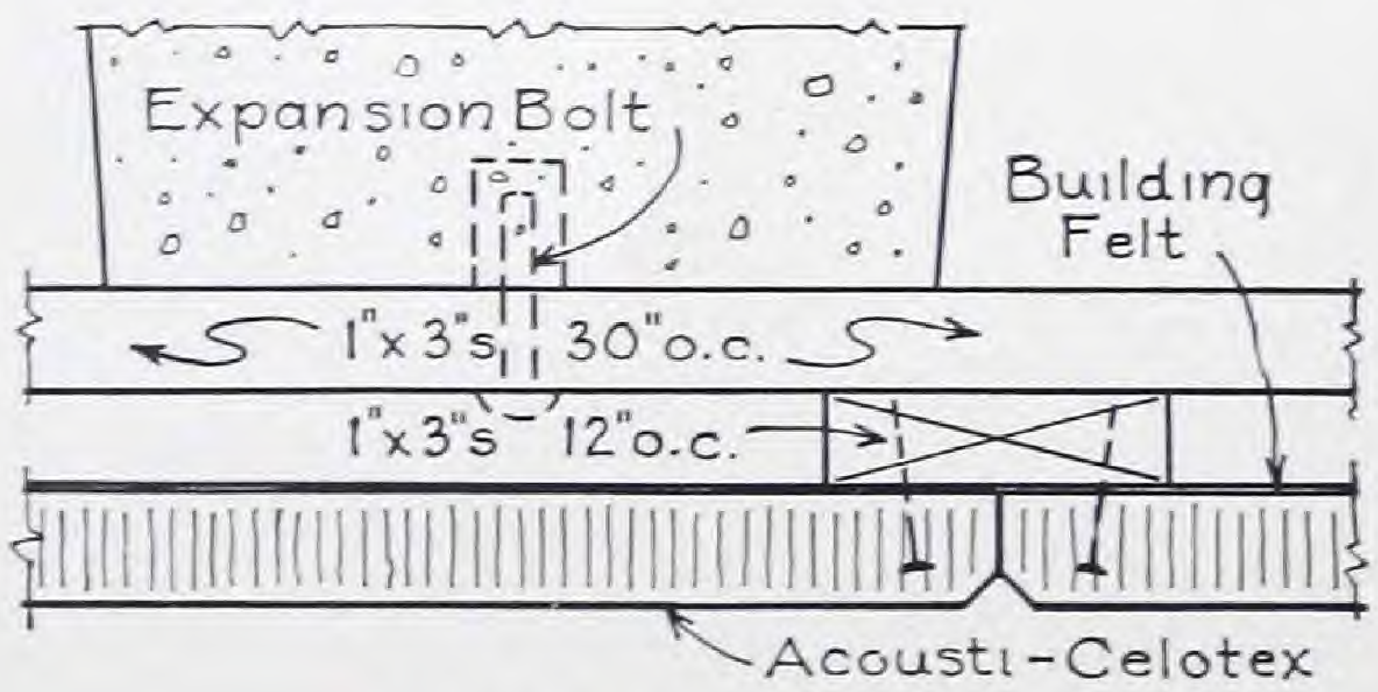


PLASTER BOARD CEILING

Where a suspended ceiling of lighter and cheaper construction than metal lath and plaster is desired, Acousti-Celotex may be fastened directly to gypsum board held by approved plaster board suspension systems.

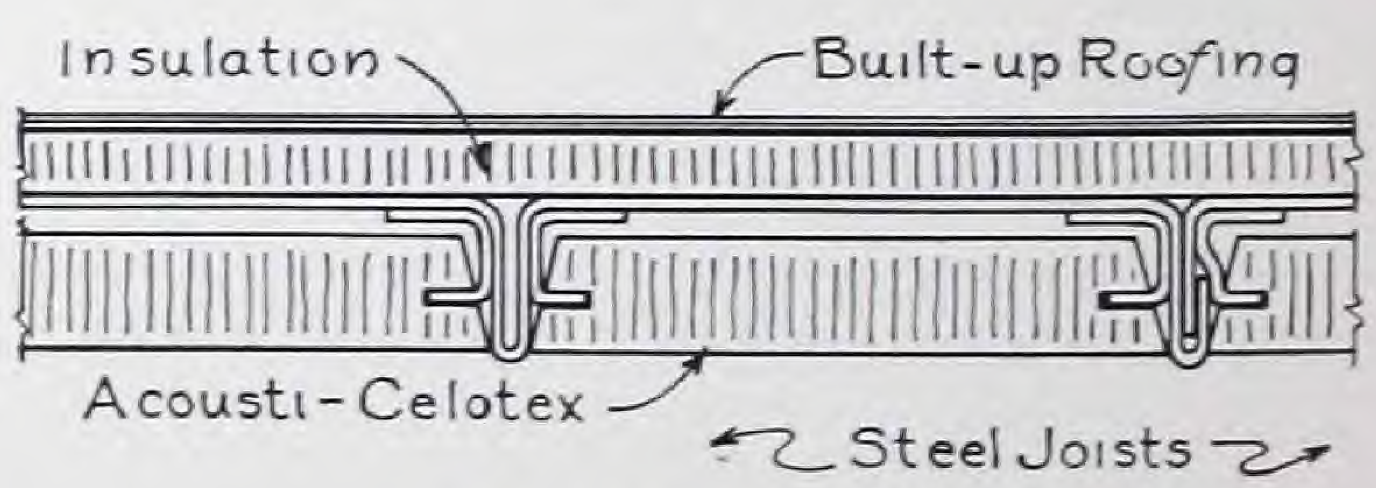
APPLICATION TO CURVED SURFACES

Sizes of Acousti-Celotex Tile are such as to facilitate installation on curved surfaces, such as arches and groined ceilings. The tile may be kerfed on the back to take sharp curves down to a radius of approximately 6 feet.



WOOD FURRING

On concrete surfaces or other surfaces where it is desired to fur down, 1″ x 3″ wood furring strips may be attached to the concrete with expansion plugs and the Acousti-Celotex nailed to the furring strips. Ordinarily a first course of strips, 30″ on center, is used, to which is nailed the second course, 12″ on center, to receive the 12″ x 12″ tiles. A backing of building felt is used directly behind the Acousti-Celotex to prevent "breathing" between joints.



STEEL DECK

Acousti-Celotex may be used in combination with steel roof decks to give a combined acoustical ceiling and steel roof deck having high heat insulating qualities. Acousti-Celotex has the same heat insulating value as an equal thickness of Celotex. Acousti-Celotex is cut to fit the steel deck and fabricated before erection.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

ACOUSTI-CELOTEX
M-Series

M-Series Acousti-Celotex is made of mineral fibres (Rockwool) felted in a manner similar to that used in the manufacture of C-Series Acousti-Celotex, but with the addition of a suitable binder. This binder is added to provide in the finished product the strength and toughness inherent in the bagasse fibre used for the manufacture of C-Series Acousti-Celotex.

As in C-Series Acousti-Celotex, sound is dissipated by friction in the minute interstices between the fibres.

Maintenance

M-Series Acousti-Celotex can be repeatedly painted with any standard paint without impairing its sound-absorbing efficiency.

Conductivity

The conductivity of M-Series Acousti-Celotex is 0.35 Btu per hour per square foot per degree Fahrenheit per inch thickness.

Moisture Resistance

M-Series Acousti-Celotex tile are integrally waterproofed during manufacture by means of a chemical treatment which prevents disintegration where the tile is accidentally submerged in water.

However, M-Series Acousti-Celotex is not recommended for use in rooms where conditions of continual excessive humidity exist.

Rodent and Vermin Resistance

M-Series Acousti-Celotex contains no food for rats, mice or other rodents or vermin. Rodents will only attack it when food or water on the opposite side attracts them, in which case they may gnaw a hole through the material as they would through plaster, wood, or even concrete. When this is done it will be noted that the fibres are left lying at the hole and are not eaten.

Fire Resistance

M-Series Acousti-Celotex is rated as incombustible.

Resistance to Impact and Abrasion

M-Series Acousti-Celotex is not recommended for traffic bearing surfaces, or where subjected to impact or abrasion.

Sizes

Standard sizes are 6″ x 12″, 12″ x 12″.

Special sizes are available at an additional cost.

The ⅛″ bevel on all four sides of the tile face is standard.

The bevels can be omitted or changed at added expense if desired.

Finishes

(1) White asbestos paint finish (WA finish).

(2) WA plus flat white or cream white paint (Standard Paint finish).

(3) WA plus white or cream white enamel (Standard Enamel finish).

Light Reflection

Light Reflection Factors by Authority of Curtis Lighting, Inc.

Mineral Tile	Diameter of Perforations
Finish	5/32″
Natural	.45
WA Finish	.60
Standard Paint Finish, white	.72
Standard Enamel Finish, white	.76

Absorption Coefficients

Absorption Coefficients and Specifications of Test Samples

Reprinted by permission from the Official Bulletin of the A.M.A., March, 1938

Types of Mounting

1. Cemented to plaster board. Considered equivalent to cementing to plaster or concrete ceiling.

Material	Thickness	Mounting (Described above)	Coefficients 128	256	512	1024	2048	*Noise Reduction Coefficient	Unit Size Tested	Wt. (lbs.) sq. ft.	Surface	Test No.
MINERAL TILE												
Acousti-Celotex, Type M1	⅝″	1	.17	.29	.58	.82	.82	.65	12″x12″	1.43	Unpainted. Perforated 676 holes per sq. ft. 5/32″ diam. ½″ deep.	64
Acousti-Celotex, Type M1	⅝″	1	.14	.24	.58	.93	.83	.65	12″x12″	1.53	Painted with oil-base paint. Perforated same as above.	73
Acousti-Celotex, Type M2	1″	1	.15	.34	.88	.95	.77	.75	12″x12″	2.12	Painted same as above. Perforated same as above.	200

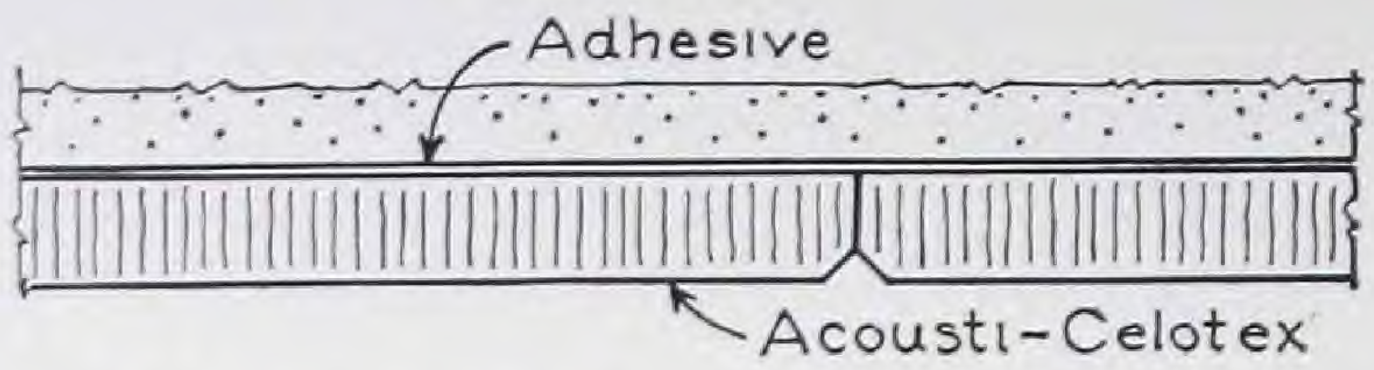
*The noise reduction coefficient is the average of the coefficients at frequencies from 256 to 2048 cycles inclusive, given to the nearest 5%. This average coefficient is recommended for use in comparing materials for noise quieting purposes as in offices, hospitals, banks, corridors, etc.

For auditorium treatment, attention should be directed to the coefficients at 512 cycles and other frequencies as explained elsewhere.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

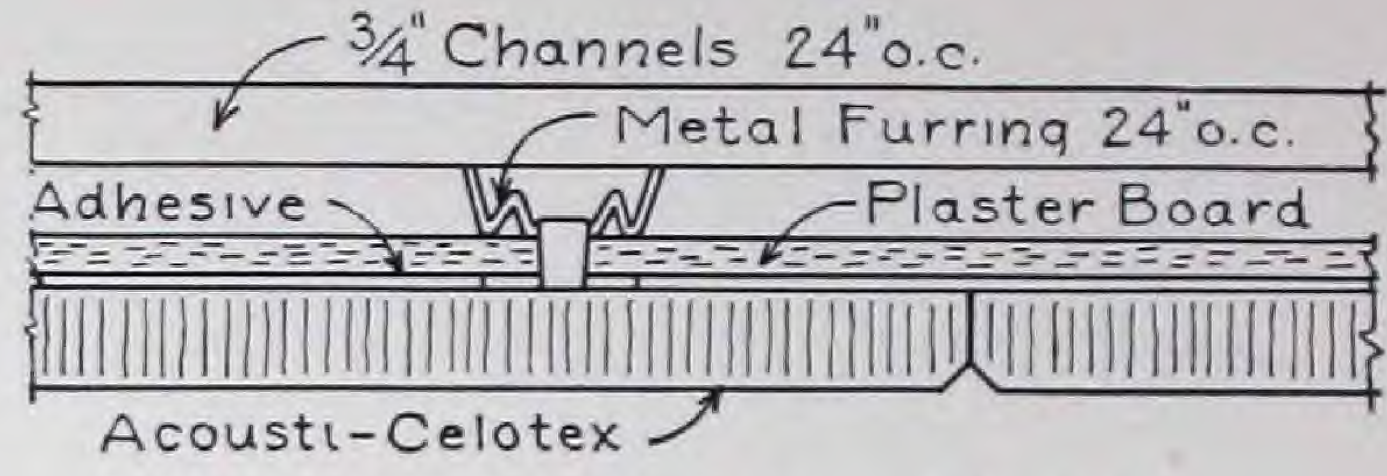
Construction Details

ACOUSTI-CELOTEX MINERAL TILE



PLASTER OR CONCRETE CEILING

Acousti-Celotex M-Series is usually applied with a heavy bodied adhesive alone to plaster or flat concrete surfaces, provided the installation is made by experienced workmen exercising necessary precautions.



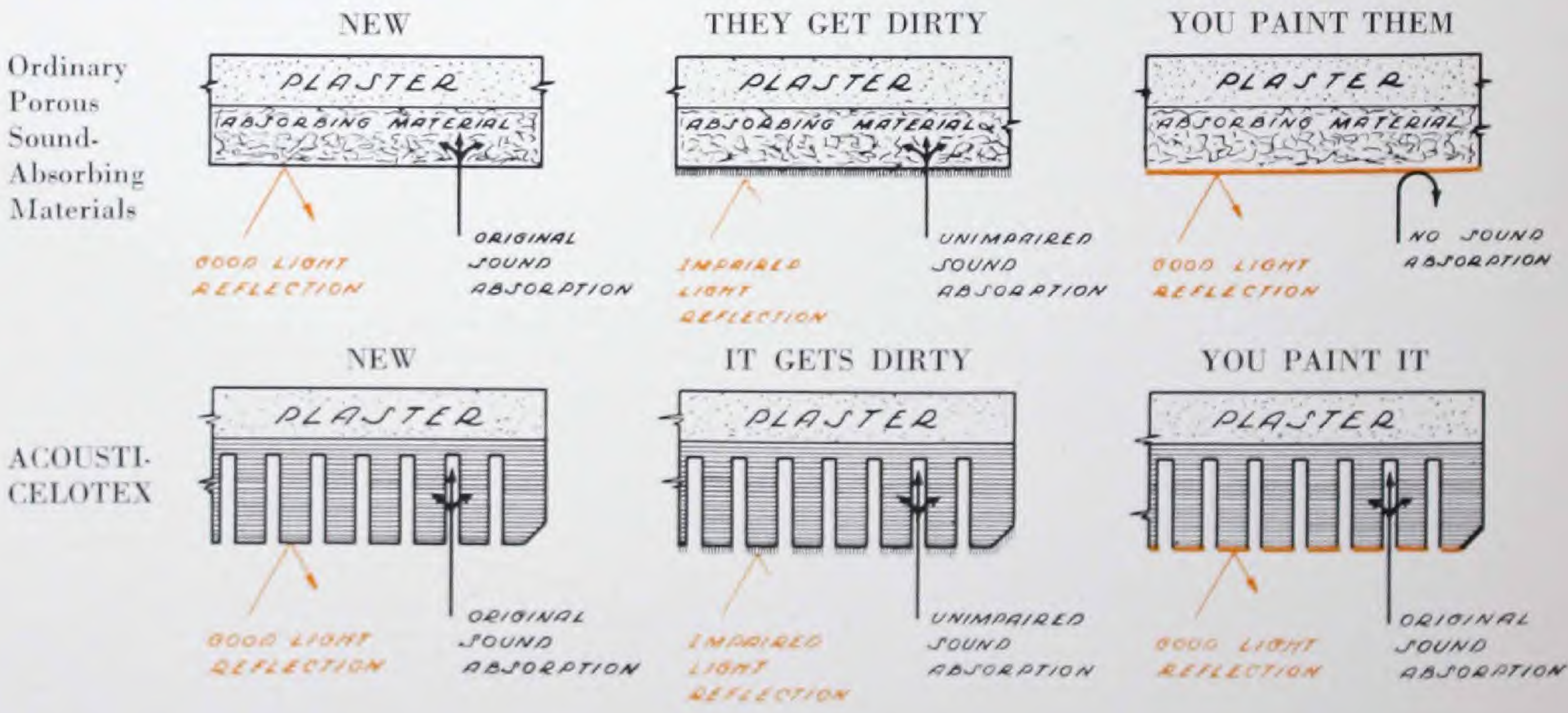
PLASTER BOARD CEILING

Where a suspended ceiling of lighter and cheaper construction than metal lath and plaster is desired, Acousti-Celotex M-Series may be fastened directly to gypsum board held by approved plaster board suspension systems.

Easy to Maintain—

Because Acousti-Celotex is perforated it may be repeatedly painted without impairing its acoustical efficiency. Special paints and special cleaning equipment are not required.

THE PAINTABILITY OF ACOUSTI-CELOTEX GIVES YOU PERMANENT SOUND ABSORPTION



LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

CALICEL

TRADE MARK

For the correction of faulty acoustics in monumental type buildings (as contrasted with office space), architects and owners have been obliged to resort to the use on ceilings or walls of acoustical materials which in appearance and character were entirely inharmonious with adjacent surfaces of travertine, caen stone, fine marble, imported wood panelling, etc. The principal reason for use of these beautiful materials is appearance.

There has therefore been an obvious need for an acoustical material that would combine in itself the double function of natural beauty and acoustical correction. Calicel offers the answer to this need.

Calicel, basically, is a highly expanded stone. It is a cellular mineral, formed at temperatures in excess of 2000° F., being so cooled that the molten mass is expanded from 10 to 40 volumes. This highly cellular structure somewhat resembles a petrified sponge. Subsequent refining and grading operations produce finished Calicel which serves as an aggregate for Calicel Acoustical Materials.

This Calicel Aggregate is carefully graded for size and color, thus making possible a wide variation of natural colors and textures in the finished product.

The actual production of Calicel Acoustical tile is like that of any standard floor or wainscot tile in that the aggregate is thoroughly mixed with a time-tried mineral bonding agent, then moulded with hydraulic presses, after which it is cured or dried in kilns.

Moisture Resistance

Calicel aggregate is unaffected by moisture. In the manufacture of Calicel tile the binder used is insoluble so that the finished product embodies moisture resistance ample for all normal conditions. Calicel tile, however, is not recommended for rooms in which abnormally high humidities are likely to exist, as in swimming pools.

Maintenance

Lacking mechanically made perforations of definite diameter, depth and spacing, Calicel does not possess the same degree of "paintability" inherent in Acousti-Celotex. Calicel is also available with a factory-applied finish, permitting cleaning by washing. Commercial wall-paper cleaners are effective in removing accumulated dust and dirt.

Conductivity

The conductivity of Calicel is .53 Btu per hour per square foot per degree Fahrenheit per inch thickness.

Rodent and Vermin Resistance

Calicel contains no food for rats, mice or other rodents or vermin. Rodents will only attack it when food or water on the opposite side attracts them, in which case they may gnaw a hole through the material as they would through plaster, wood or even concrete.

Fire Resistance

Calicel tile and Calistone contain no combustible matter.

Resistance to Impact and Abrasion

Calicel tile is not recommended for use where subject to impact and abrasion.

Sizes

The standard sizes of Standard, Italian, and Tapestry are 6″ x 12″, 12″ x 12″, 12″ x 24″.

Finishes

Standard—The natural finish is of a slightly variegated light ivory color. Also available prepainted, in either standard white or cream white.

Italian—This type is effectively used in combination with the Standard type for decorative contrast. Of the same texture as the Standard type, the different finish is obtained by a sprinkling of natural dark, golden reddish brown, and black particles on a fine texture ivory field.

Tapestry—This type is also effective for decorative contrast in combination with the Standard and Italian types. The texture is different being formed by the use of coarser graded aggregates. The coloring is similar to that of the Italian type, being obtained by a sprinkling of natural dark, golden reddish brown and black colored particles on a coarse texture ivory field.

Application

Two different methods of application are recommended, namely:

1. Cemented direct to plaster or other masonry wall with a plastic, heat-resisting, moisture proof cement.
2. Supported mechanically by a system of special metal members—whereby lath and plaster may be eliminated.

Absorption Coefficients

ABSORPTION COEFFICIENTS AND SPECIFICATIONS OF TEST SAMPLES

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Types of Mounting

1. Cemented to plaster board. Considered equivalent to cementing to plaster or concrete ceiling.
10. Mounted on special metal supports. 2" Rock Wool blanket 2.36 lbs./sq. ft. behind unit.

MATERIAL	Thickness	Mounting (Described Above)	Coefficients					*Noise Reduction Coefficient	Unit Size Tested	Wt. (lbs.) sq. ft.	Surface	Test No.
			128	256	512	1024	2048					
Calicel												
Standard	3/4"	1	.16	.19	.57	.95	.71	.60	12"x12"	2.06	Unpainted	212
Standard	3/4"	1	.15	.22	.58	.96	.76	.65	12"x12"	2.12	Painted by Mfgr. Oil base paint.	215
Standard	1"	1	.20	.29	.76	.97	.79	.70	12"x12"	2.75	Unpainted	213
Standard	1"	1	.20	.27	.76	.99	.81	.70	12"x12"	2.56	Painted by Mfgr. Oil base paint.	216
Standard	1"	10	.59	.69	.99	.91	.81	.85	12"x12"	2.87	Unpainted	241
Tapestry	3/4"	1	.13	.20	.64	.89	.65	.60	12"x12"	1.96	Unpainted	217
Tapestry	1"	1	.18	.32	.83	.82	.67	.65	12"x12"	2.84	Unpainted	218
Tapestry	1 1/4	1	.27	.41	.81	.66	.57	.60	12"x12"	3.45	Unpainted	292

*The noise reduction coefficient is the average of the coefficients at frequencies from 256 to 2048 cycles inclusive, given to the nearest 5%. This average coefficient is recommended for use in comparing materials for noise quieting purposes as in offices, hospitals, banks, corridors, etc.

For auditorium treatment, attention should be directed to the coefficients at 512 cycles and other frequencies as explained.

CALISTONE

TRADE MARK

Calistone is made from selected Calicel aggregates to which are added certain Portland cements. The material is moulded with hydraulic presses and cured in kilns under steam pressure. Thoroughly resistant to moisture, Calistone may be safely used even in rooms where abnormally high humidities are likely to exist, as in swimming pools.

Calistone is made in a minimum thickness of 1", and in sizes and shapes to meet special designs. Sizes and shapes can be prepared within the limits of any standard stone and erected in the same manner.

Calistone permits the architect the same latitude he has enjoyed in the design and specification of natural stone. Its appearance is similar to that of any sand finished stone and special textures and colors can be produced.

ABSORPTION COEFFICIENTS AND SPECIFICATIONS OF TEST SAMPLES

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Types of Mounting

4. Laid directly on laboratory floor.

MATERIAL	Thickness	Mounting (Described Above)	Coefficients					*Noise Reduction Coefficient	Unit Size Tested	Wt. (lbs.) sq. ft.	Surface	Test No.
			128	256	512	1024	2048					
Calistone	1"	4	.16	.28	.60	.89	.66	.60	12"x12"	4.61	Unpainted	220
Calistone	2"	4	.36	.58	.77	.69	.63	.65	12"x12"	9.82	Unpainted	221

*The noise reduction coefficient is the average of the coefficients at frequencies from 256 to 2048 cycles inclusive, given to the nearest 5%. This average coefficient is recommended for use in comparing materials for noise quieting purposes as in offices, hospitals, banks, corridors, etc.

For auditorium treatment, attention should be directed to the coefficients at 512 cycles and other frequencies as explained.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

Calicel Acoustical Castone

In recent years with the growing appreciation of the desirability of acoustical treatment in auditoriums, court rooms, railroad station waiting rooms and public rooms of monumental structures, many architects have felt the need of an acoustical material for ceilings or walls adaptable to rich ornamentation.

To meet this need, The Celotex Corporation in conjunction with Jacobson & Company, Inc. is now offering Calicel Acoustical Castone.

Architectural Effect

There is almost no architectural effect achievable with ordinary casting plaster which cannot be reproduced using Calicel Acoustical Castone. Intricate coffers, elaborate friezes, panels and mouldings can be sharply cast and with an unusual amount of detail. The texture of the material itself can be varied from coarse to fine through the proper screening of the aggregate used. And in addition to the variation in color which can be obtained through the mixture of the different colored aggregates, a tone variation can be achieved from pale gray to the deeper shades of gray.

Calicel Aggregate

Calicel is the trade name of an exceedingly light aggregate made of stone expanded into globules by a patented process. Through the admixture of other materials it can be cast into a stone which is hard and durable, pleasing in appearance and of sufficient porosity to give it definite acoustical value.

Acoustical Effect

In tests which The Celotex Corporation has conducted sound absorption coefficients at 512 cycles from .40 to .60 have been obtained on different thicknesses.

When Calicel Acoustical Castone is used in ceilings of an ornamental nature, the developed area of the ceiling amounts to as much as 50% or 60% more than the flat area of the floor space which it covers. Accordingly, in ceiling treatment of this type, higher effective values are obtained.

Decoration

While the entire surface of Calicel Acoustical Castone may be painted when new without noticeable loss of acoustical efficiency, ornamented parts of the ceiling can be colored or gold and silver leaf applied without any appreciable loss. This is especially true where the developed surface area, owing to the richness of the ornament, is sufficiently large.

Durability

While Calicel Acoustical Castone presents a hard even surface that will not sand, scale or rub off, yet it is not recommended for traffic-bearing surfaces. On ceilings, however, or above wainscot heights it will give satisfactory service for the life of the building. In areas where the material may be subjected to excessive humidity or the possibility of a damp condition in the walls, Calicel Acoustical Castone can be produced with binders of hydraulic gypsums and certain chemicals making it reasonably unaffected by moisture.

A Word About Jacobson

In the manufacture of Calicel Acoustical Castone, The Celotex Corporation has enlisted the services and facilities of Jacobson & Company, Inc., of New York, one of the few nationally known fabricators of cast plaster and stone interior ornament. Jacobson by virtue of their wealth of experience, have gained the respect of architects and builders in all parts of the country. Calicel aggregate is shipped to their completely equipped ornament shop and there, either from the Jacobson library of stock models or from models specially made, Calicel Acoustical Castone is cast to fit the requirements of the individual job. When the size of casts makes shipment difficult, models are shipped and the ornament cast on the job site.

Price

Because of the wide range in design possible with Calicel Acoustical Castone and the variation of specific job conditions, no unit prices can be quoted. Plans and drawings delivered to any local Celotex Acoustical distributor will be forwarded to Jacobson for either budgetary figures or final estimates.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

VIBRAFRAM

TRADE MARK

(FORMERLY HEERWAGEN TILE)

In principle, Vibrafram departs radically from conventional acoustical materials of porous composition. It depends for its sound-absorbing qualities on diaphragmatic vibration of the individual tile units.

To understand The Celotex Corporation's adoption and endorsement of this product, it is necessary to take a retrospective view of the modern science of acoustical correction.

Acoustical material is needed for the correction of excessive reverberation in rooms where speech and music are carried on. Conventional sound-absorbing materials adequately absorb high-pitched sounds but provide inadequate absorption for sounds in the lower frequencies. This characteristic accounts for the "dead" condition occasionally complained of by musicians in acoustically treated rooms, and particularly affects the problem of correction in sound picture theatres.

Acoustical engineers, therefore, for several years have recognized the need for an acoustical material that would develop high efficiency in the low frequency range. With conventional acoustical materials of porous composition, the desired result has been approached only by increasing the thickness by several inches or by applying thinner material on furring strips so that it would have the ability to vibrate.

The principle of absorption by diaphragmatic vibration therefore is not a new discovery, but it has remained for Mr. Paul M. Heerwagen, the inventor of Vibrafram, first to give it expression in practical form.

Vibrafram (formerly Heerwagen Tile) is a tile made of fireproofed felt of about the thickness of billiard-table felt. The felt is sized and formed into plain or ornamental hollow tile shapes which retain the vibratory quality required. The tile are extremely light in weight—approximately 3 ounces per square foot, and are applied by fastening with an approved adhesive directly against the plaster, wall-board or concrete wall or ceiling surface.

Vibrafram has a negligible heat insulating value. It is not recommended for application on traffic-bearing areas where subject to bodily contact and should not be used in rooms where excessively high humidity may exist, as in swimming pools.

With Vibrafram, many pleasing decorative effects are possible by the proper design and layout of areas to be treated. The natural color is light cream. While authoritative test data on the effect of paint is not available at the time this is printed, many installations have been painted for decorative color effects without noticeable injury to the absorptivity.

Application

Surfaces to which Vibrafram are to be applied, such as concrete, plaster or wallboard should be firm and cleaned of calcimine, white wash or loose paint. Surfaces to be treated are scored and chalk lined both ways in 13″ squares and approved adhesive is then applied to all half-inch margins of the tile which are then applied and pressed firmly into position.

Here are three standard designs in Vibrafram tile. These provide agreeable patterns to harmonize with established interior decorative schemes, from the plain to the ornate.

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

ABSORBEX

TRADE MARK

Absorbex is a cement-timber product, made by a process which shreds timber into long tough fibers, then passes them through a binding emulsion of high temperature cement. The entire mass is then formed between rolls and steel belts at a temperature of 500 degrees F. into fire retarding slabs, uniform in thickness, containing millions of minute air cells, affording high insulation, great structural strength, fireproofness, and superior acoustical value.

Maintenance

Absorbex can be cleaned and painted without materially affecting the initial efficiency. The paints used and their method of application are important factors, and the manufacturer should be consulted before painting is undertaken.

Conductivity

The thermal conductivity of Absorbex is .46 Btu per hour per sq. ft. per degree Fahrenheit per inch thickness.

Moisture Resistance

Absorbex is adequately waterproofed for all normal room conditions. It is not recommended for use where conditions of continual excessive humidity exist.

Rodent and Vermin Resistance

Made of clean, shredded wood, with each strand coated with high temperature cement, Absorbex is odorless and affords no food value to attract insects. Rodents will only attack it when food or water on the opposite side attracts them, in which case they may gnaw a hole through the material as they would through plaster, wood or even concrete.

Fire Resistance

Absorbex is highly fire-resistant. Standard flame tests as required by the Departments of Buildings, New York City, for determining the fire resisting qualities of acoustical materials were conducted by Columbia University on Absorbex. This test consisted of the application of a semi-luminous flame from an air-gas burner with $\frac{3}{4}$-in. nozzle to the exposed surface. Temperature was gradually increased to 1700 degrees F. for one-half hour, and maintained at this temperature for an additional ten-minute period. Temperatures were recorded by Thermo-couples. The material did not flame or give off smoke or noxious fumes—thus rating the material fire retarding, permitting its unlimited use in fireproof construction.

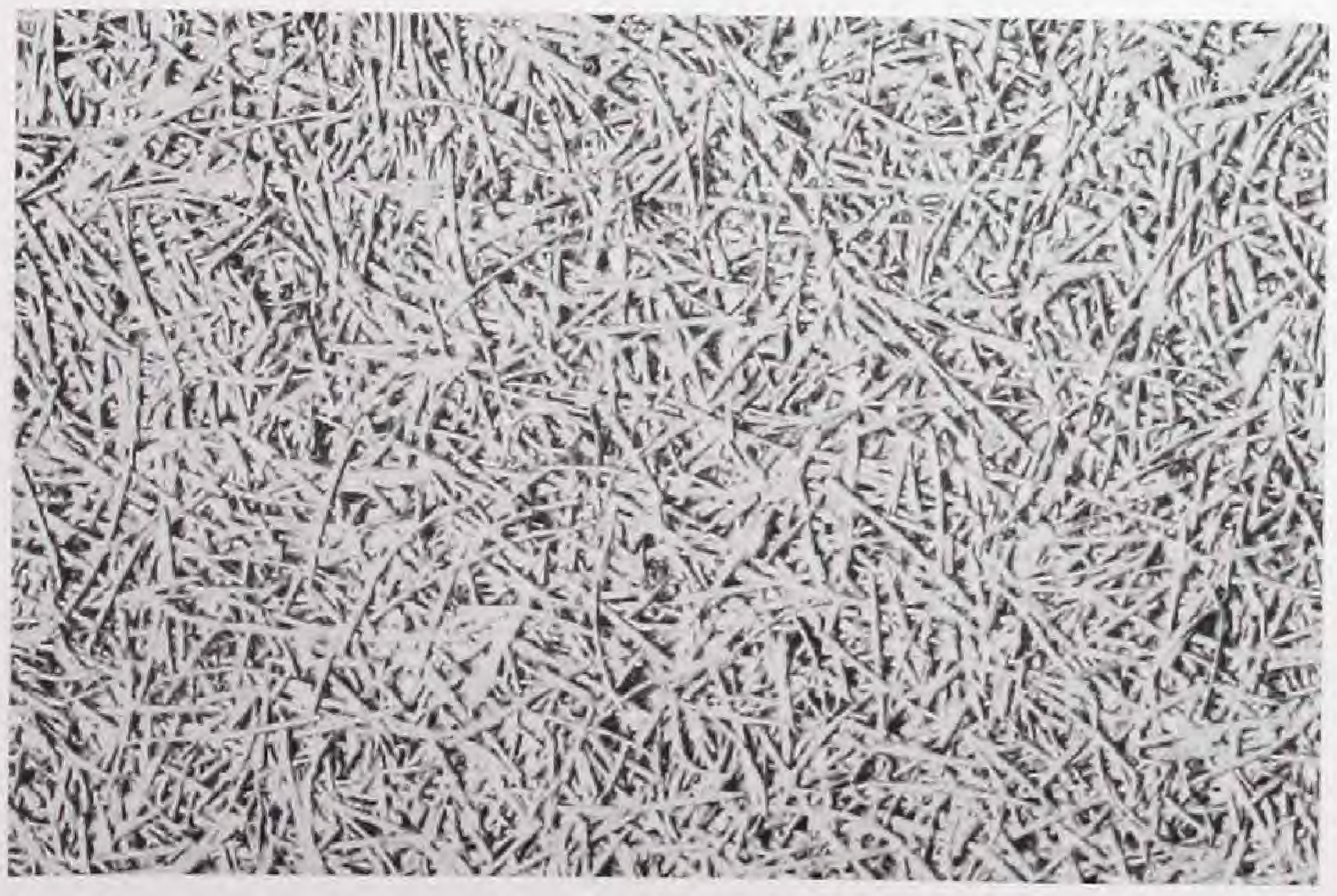
Resistance to Impact and Abrasion

Absorbex is tough, hard and strong and successfully withstands normal ball impacts as in gymnasiums, or body contact on lower wall areas.

Sizes

Type A standard sizes are 9x9″, 9x18″, 18x18″, 18x36″, and 18x54″, 1″ thick.

A $\frac{3}{16}$″ bevel on all four sides of the tile face is standard. Bevels can be omitted, or changed at added expense.



Type A Absorbex—Full Size

Type C Absorbex—Full Size

Type F Absorbex—Full Size

FIFTH REGIMENT ARMORY, BALTIMORE, MD.
Type F Absorbex Laid in Tees Used as Roof Deck and Acoustical Treatment

Sizes (Cont'd)

Type C Absorbex is furnished in slabs 20″ wide by 32″, 48″, or 64″ long, 1″ in thickness, and with square cut edges only.

Type F Absorbex is furnished in slabs 20″ wide, 48″ or 64″ long and in 1″ or 2″ thickness. Slabs of 3″ thickness are furnished 20″ wide, 32″, 48″, or 64″ long. All sizes have square cut edges only. Types C and F may be satisfactorily placed in concrete forms without mechanical ties.

Finishes

Accompanying photographs show the texture finishes of Types A, C and F. Only Type A is available in beveled edge tile.

Light Reflection

The light reflection of Absorbex Type A natural finish, according to a recognized testing laboratory, is 45%. Tests by the same laboratory on Absorbex Type A, spray-painted with a good grade of oil base paint, show an average value of 73% for ivory color, and 79% for white color. Except where light reflection is unimportant, as in the case of certain high-ceilinged rooms, it is recommended that Absorbex Types C and F be spray-painted.

Absorption Coefficients

ABSORPTION COEFFICIENTS AND SPECIFICATIONS OF TEST SAMPLES

Reprinted by permission from the Official Bulletin of the A.M.A., March, 1938

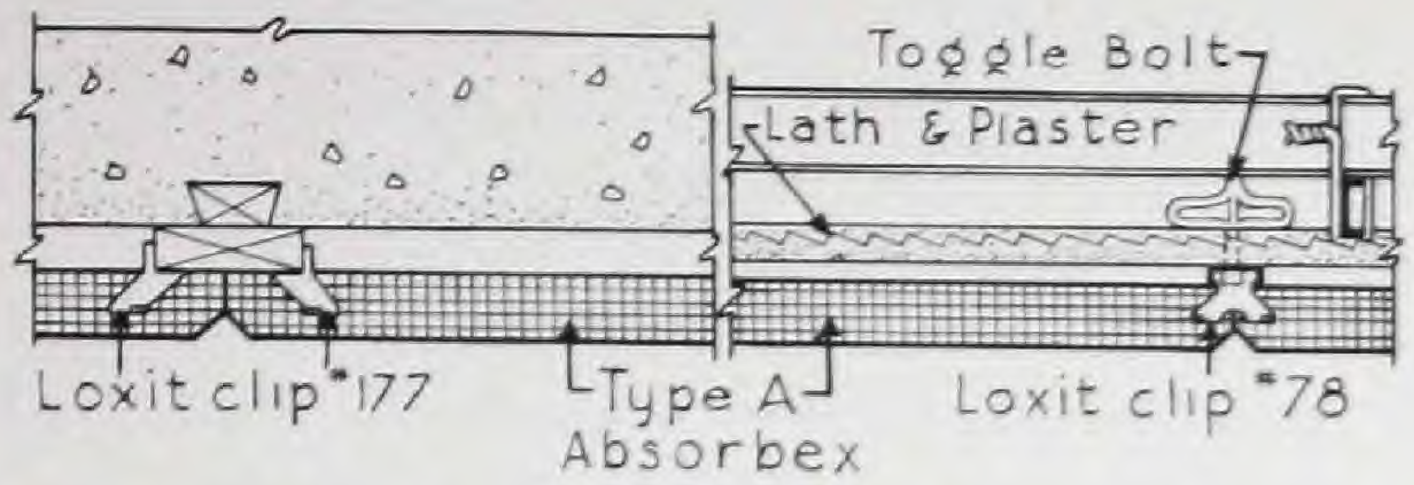
Types of Mounting

1. Cemented to plaster board. Considered equivalent to cementing to plaster or concrete ceiling.
2. Nailed to 1″ x 2″ wood furring 12″ o.c. unless otherwise indicated.
5. Tile nailed to 1″ x 3″ wood furring 18″ o.c. and filled in between furring 1″ mineral wool.
7. Tile nailed to 2″ x 4″ studs, 18″ o.c., and filled between studs with 3½″ thick mineral wool.
11. 1″ Absorbex Type A spot-cemented to 1″ Absorbex Type F.

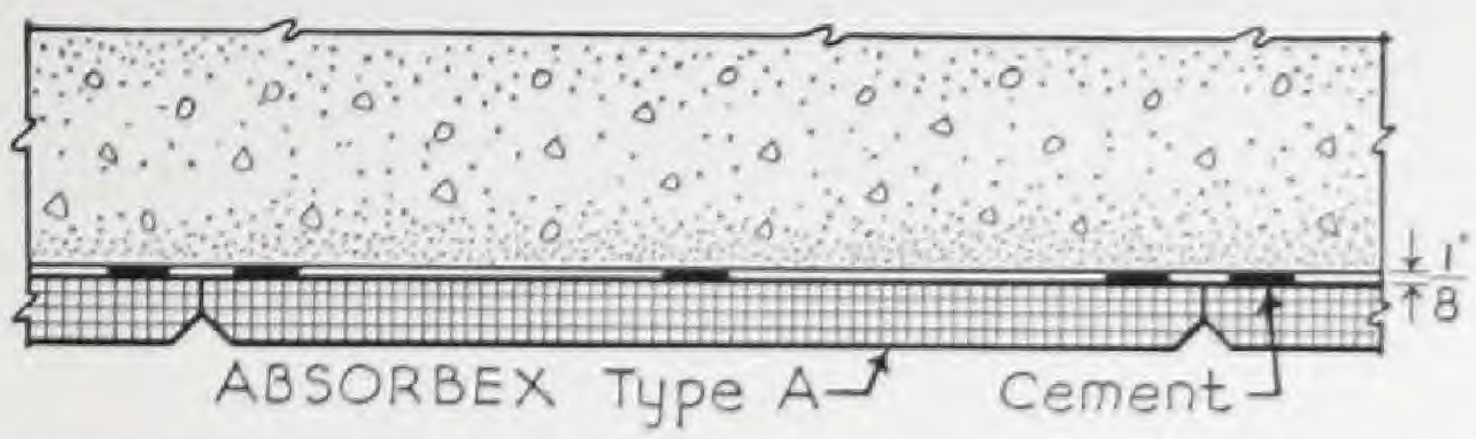
MATERIAL	Thickness	Mounting (Described above)	Coefficients 128	256	512	1024	2048	*Noise Reduction Coefficient	Unit Size Tested	Weight (lbs.) Sq. Ft.	Surface	Test No.
Absorbex, Type A	1″	1	.18	.26	.63	.96	.77	.65	18″x18″	2.63	Painted by mfgr. with oil-base paint.	207
Absorbex, Type A	1″	2 (18″ o.c.)	.20	.35	.86	.90	.72	.70	18″x18″	2.63	Same as above.	206
Absorbex, Type A	1″	11	.32	.50	.95	.96	.80	.80	18″x18″	4.60	Same as above.	11
Absorbex, Type A	1″	5	.58	.77	.98	.92	.79	.85	18″x18″	Unit 2.29	Same as above.	104
Absorbex, Type A	1″	7	.91	.99	.87	.84	.88	.90	18″x18″	Unit 2.44	Same as above.	162
Absorbex, Type C	1″	1	.15	.23	.40	.66	.62	.50	20″x64″	2.01	Same as above.	49
Absorbex, Type C	1″	2 (16″ o.c.)	.21	.27	.48	.63	.54	.50	20″x64″	2.01	Same as above.	48
Absorbex, Type F	1″	2 (16″ o.c.)	.11	.17	.49	.68	.63	.50	20″x64″	2.14	Same as above.	9
Absorbex, Type F	1″	5	.45	.69	.81	.64	.64	.70	20″x64″	Unit 2.54	Same as above.	110
Absorbex, Type F	2″	1	.21	.44	.85	.70	.72	.70	20″x64″	4.22	Same as above.	14

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

Absorbex Installation Details

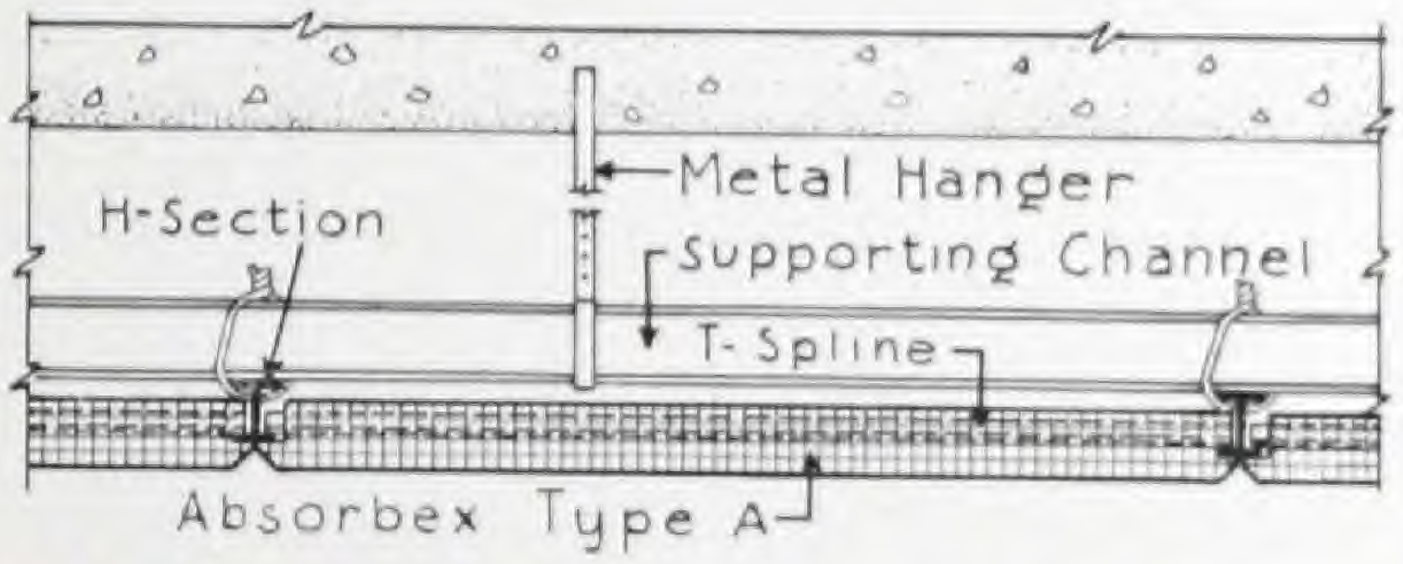


Absorbex Type A applied by Loxit system against concrete or plaster.

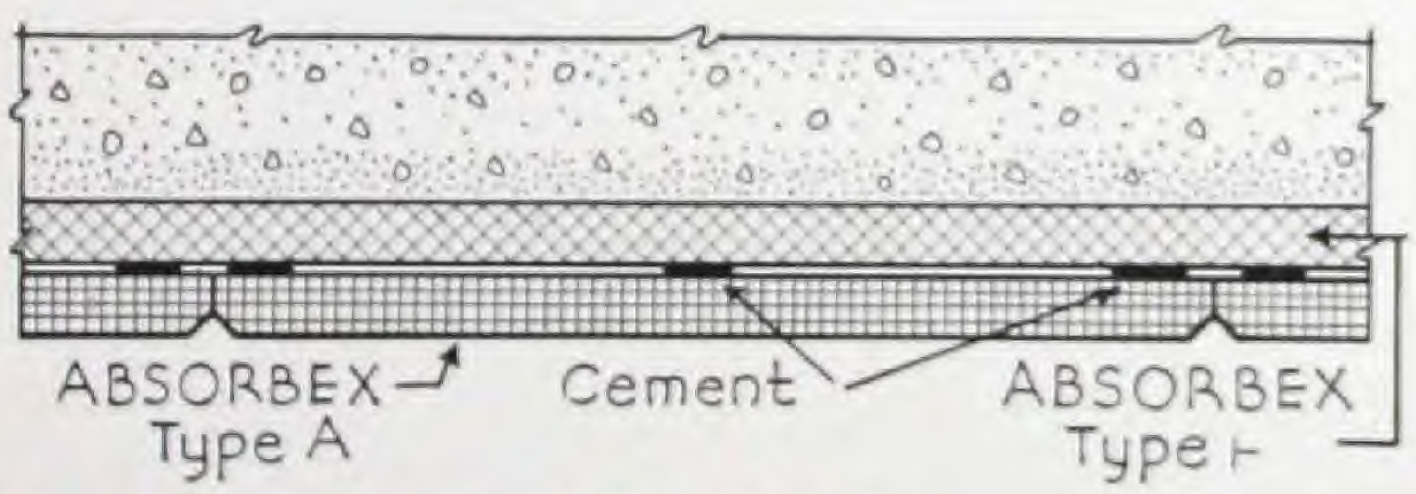


Absorbex Type A, 1" Beveled Tile, spot cemented to the plaster or concrete ceiling.

On plaster ceilings Absorbex is usually cemented (using an approved adhesive) and nailed directly to the plaster. If desired, Absorbex may be applied with an approved heavy bodied adhesive to a surface such as concrete surfaces, provided the installation is made by experienced workmen exercising necessary precautions.

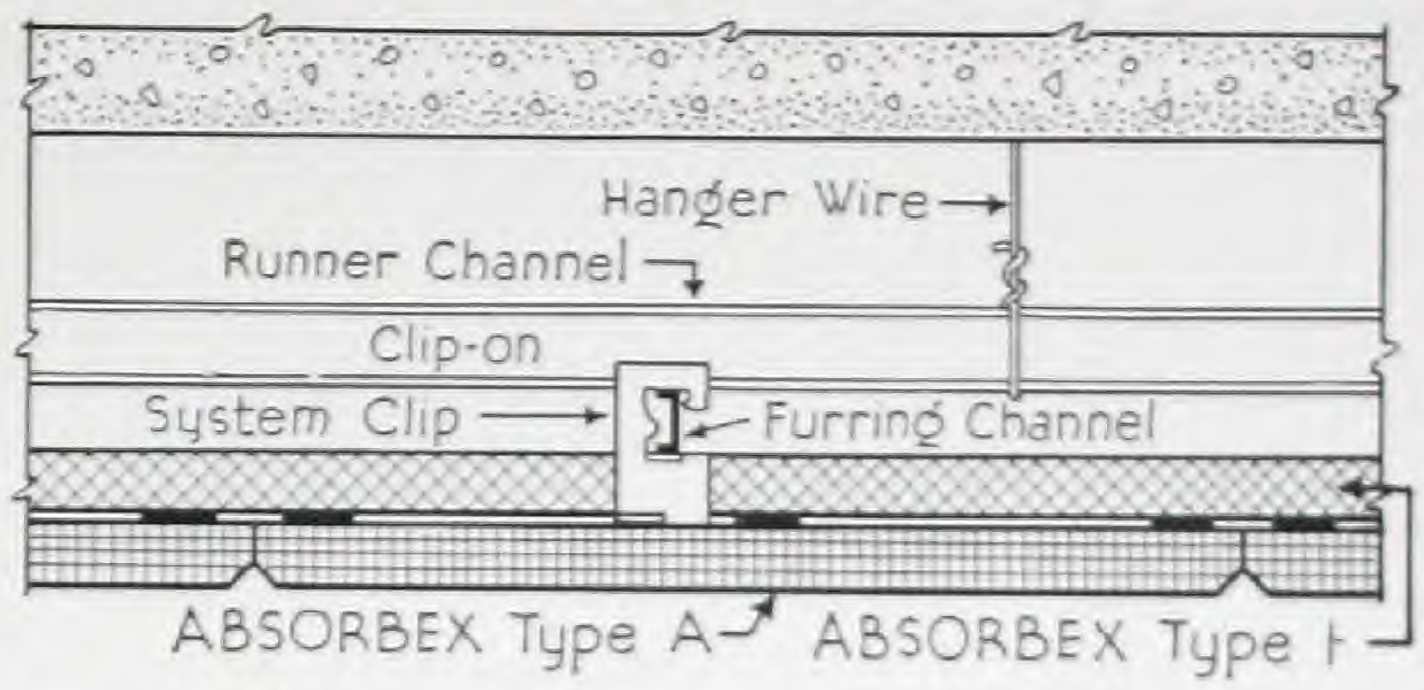


Absorbex Type A applied on Celotex Suspension System.

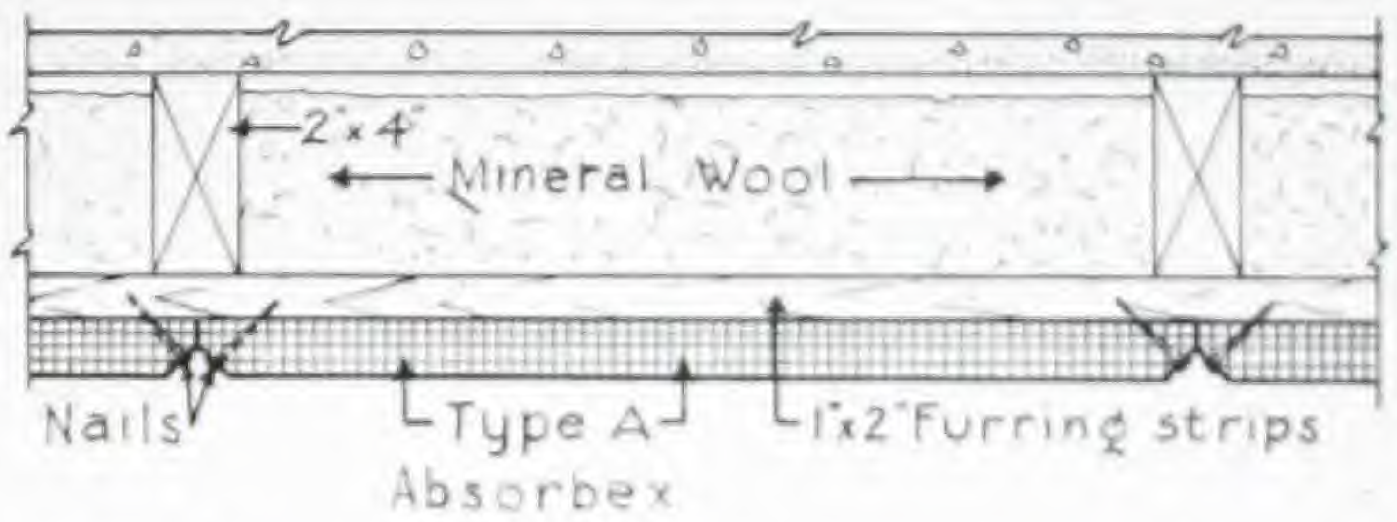


Absorbex Type A, 1" Beveled Tile, spot cemented to Absorbex Type F.

NOTE: The Type F material may be either laid in the forms at the time the concrete is poured or securely attached afterwards directly to the concrete slab with expansion bolts or dryvins.



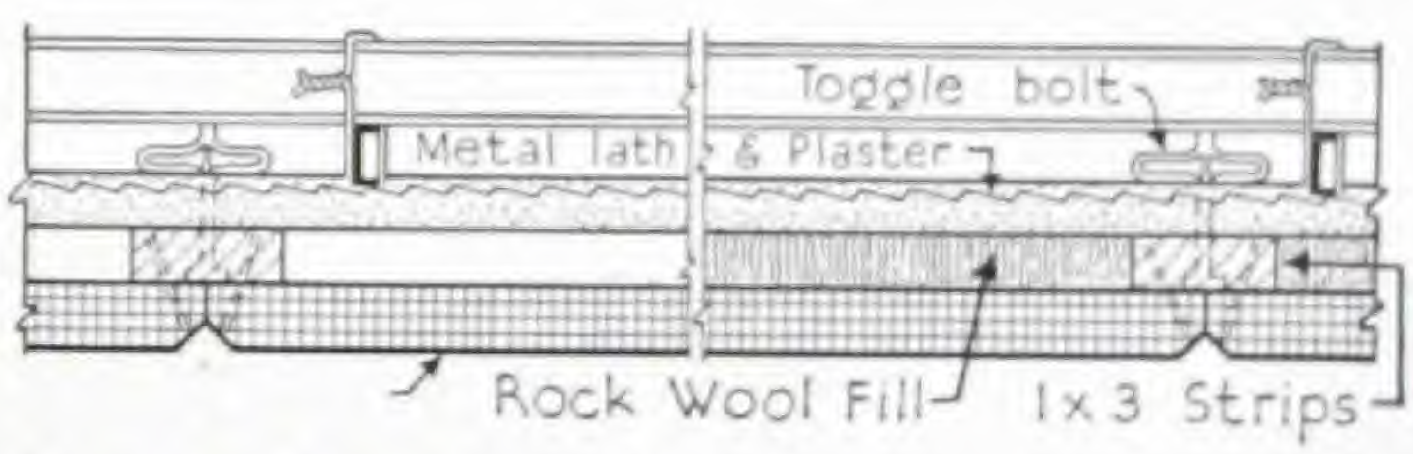
Suspended Ceiling Construction Absorbex Type A, 1" Beveled Tile when applied to Absorbex Type F is usually cemented and nailed.



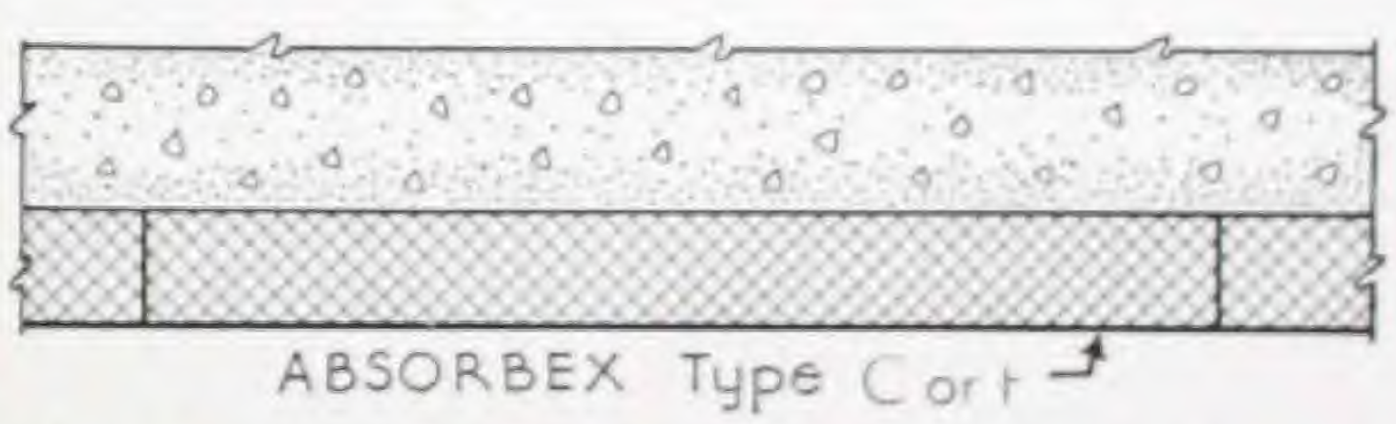
Absorbex Type A nailed to furring strips, 18" o.c. on 2 x 4's and filled with 3½" Mineral Wool between 2 x 4's.

METAL SUSPENSION

Where it is desired to use Absorbex as the suspended ceiling by itself, the tiles are supported by metal members fastened to suspended metal furring. Details of this type of construction are available on request.



Absorbex Type A, 1" Beveled Tile nailed to 1x3 furring strips. Furring strips toggle bolted to ceiling.



Absorbex Type C or F unbeveled, laid in concrete forms.

Noise Quieting

TO discuss the subject of noise quieting, it is necessary that some mention be made of the general behavior of sound. When a sound is made in a room, sound waves spread from the source at a speed of approximately 1100 feet per second. They very quickly strike the interior surfaces of the room and are partially reflected and partially absorbed. That portion of the sound wave which is reflected continues in its path until it strikes another surface, whereupon the performance is repeated. Since most building materials, such as glass, plaster, wood, etc., reflect over 95 per cent of the sound energy that strikes them, sound waves continue to be reflected hundreds of times before enough of the energy is absorbed to make the sound inaudible.

When a continuous sound is made in a room with highly reflecting surfaces, these reflections tend to build up the sound intensity to a point much greater than would result from the same source without reflection. If some of these surfaces are made absorbent, the reflections from them are much reduced, and consequently the total intensity attains a lower level than before.

This action is directly analogous to the case in illumination in which without changing the light source the light intensity may be greatly increased by the use of white surfaces (light reflecting) and decreased if some of them are painted black (light absorbing).

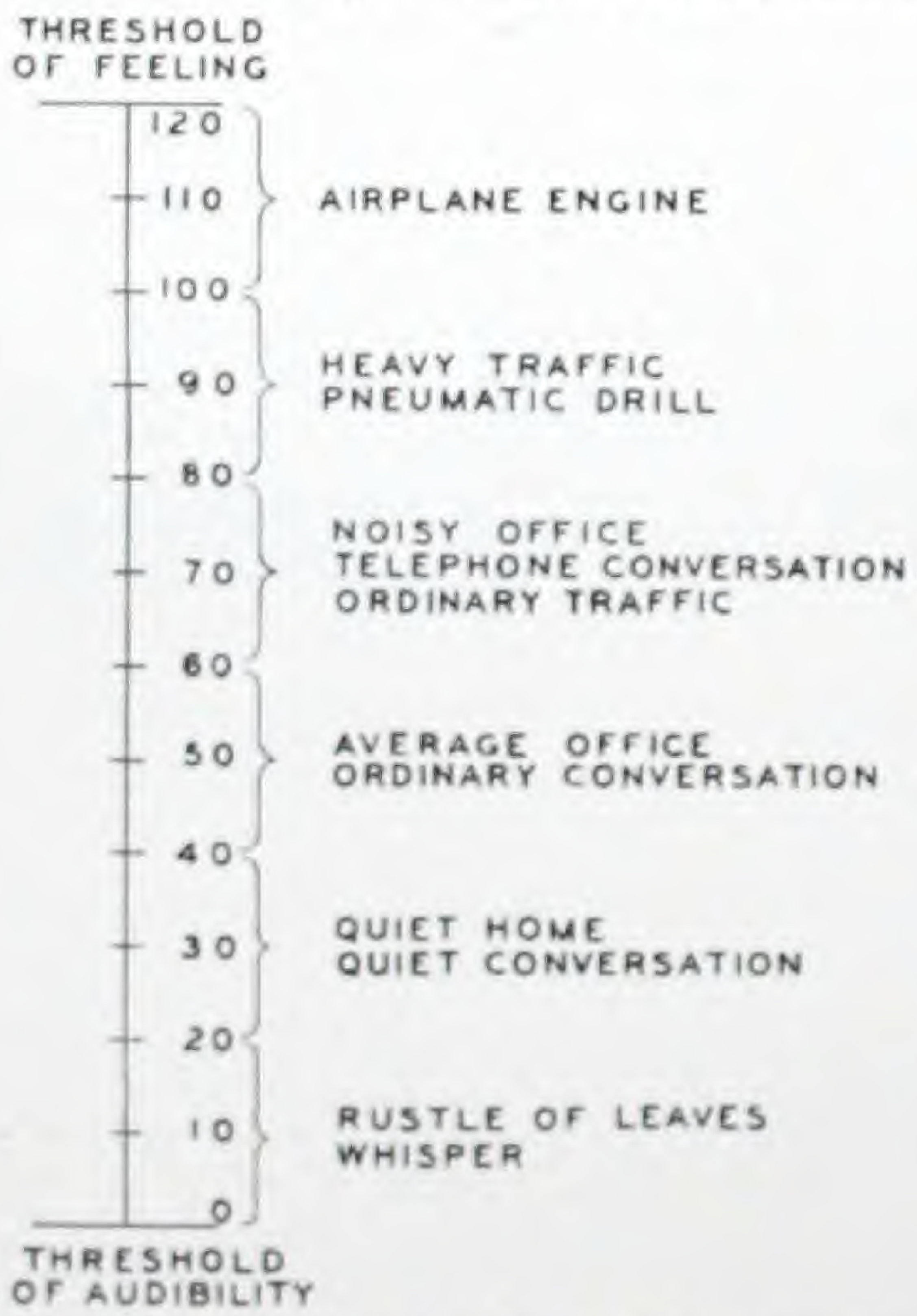


Fig. 1. The decibel scale, showing the approximate intensity levels of common sounds

Calculating Noise Reduction—Decibel Scale

It has become common engineering practice to state the quieting effect of treatment in a given room in terms of the reduction of the noise level in decibels or simply as a so-called "decibel reduction." The decibel (db.) is a logarithmic unit of sound intensity adopted for convenience in handling the extremely large range of intensities which the human ear is capable of hearing. Sound intensities when stated in decibels are referred to as "intensity levels" or, in the case of noise, as "noise levels."

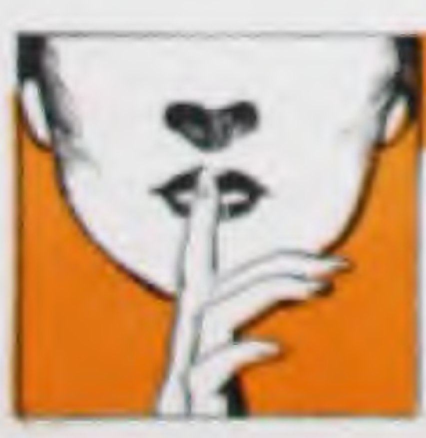
An intensity level of 0 db. corresponds to the physical intensity of a sound just too faint to be heard by the normal ear (10^{-16} watts per sq. cm.). A level of 10 db. corresponds to 10 times the original intensity, 20 db. to 100 times the original, 30 to 1000; and so on. An increase of 1 db. in intensity level corresponds to an increase of 26% in intensity and a decrease of 1 db. to a decrease of 21% in intensity. The highest intensity level which the ear can receive without actually feeling pain is about 120 db., which corresponds to an intensity one trillion times the original. Figure 1 gives an idea of the intensity levels of ordinary sounds.

The reduction in intensity level in decibels corresponding to a reduction in intensity from I_1 to I_2 is defined by the relation

$$\text{Reduction in decibels} = 10 \log_{10} \frac{I_1}{I_2}$$

From the theory of reverberation, it can be shown that the average intensity of sound in a room is inversely proportional to the total amount of absorption in the room, and depends on no other factor, providing the output of the sound source is not changed. For example, doubling the absorption would halve the intensity, and increasing the absorption five times would reduce the intensity to one fifth. Expressed mathematically,

$$\frac{I_1}{I_2} = \frac{a_2}{a_1}$$



LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

where I_1 and a_1 are the intensity and absorption, respectively, before treatment, and I_2 and a_2 are the intensity and the total absorption after the absorption is increased by treatment. Substituting this in the previous formula gives the desired relation between decibel reduction and absorption:

$$\text{Reduction in decibels} = 10 \log_{10} \frac{a_2}{a_1}$$

This relation is shown graphically in Figure 2.

If the absorption in a room is calculated to be 100 units, the addition of 300 units will make the ratio a_2/a_1 equal 4 and the loudness reduction will therefore be 6 db. It will be necessary to add 900 units or 3 times as much absorption to make the reduction 10 db. or not quite twice as great.

To calculate the absorption of any room, the area in square feet of each surface is multiplied by its absorp-

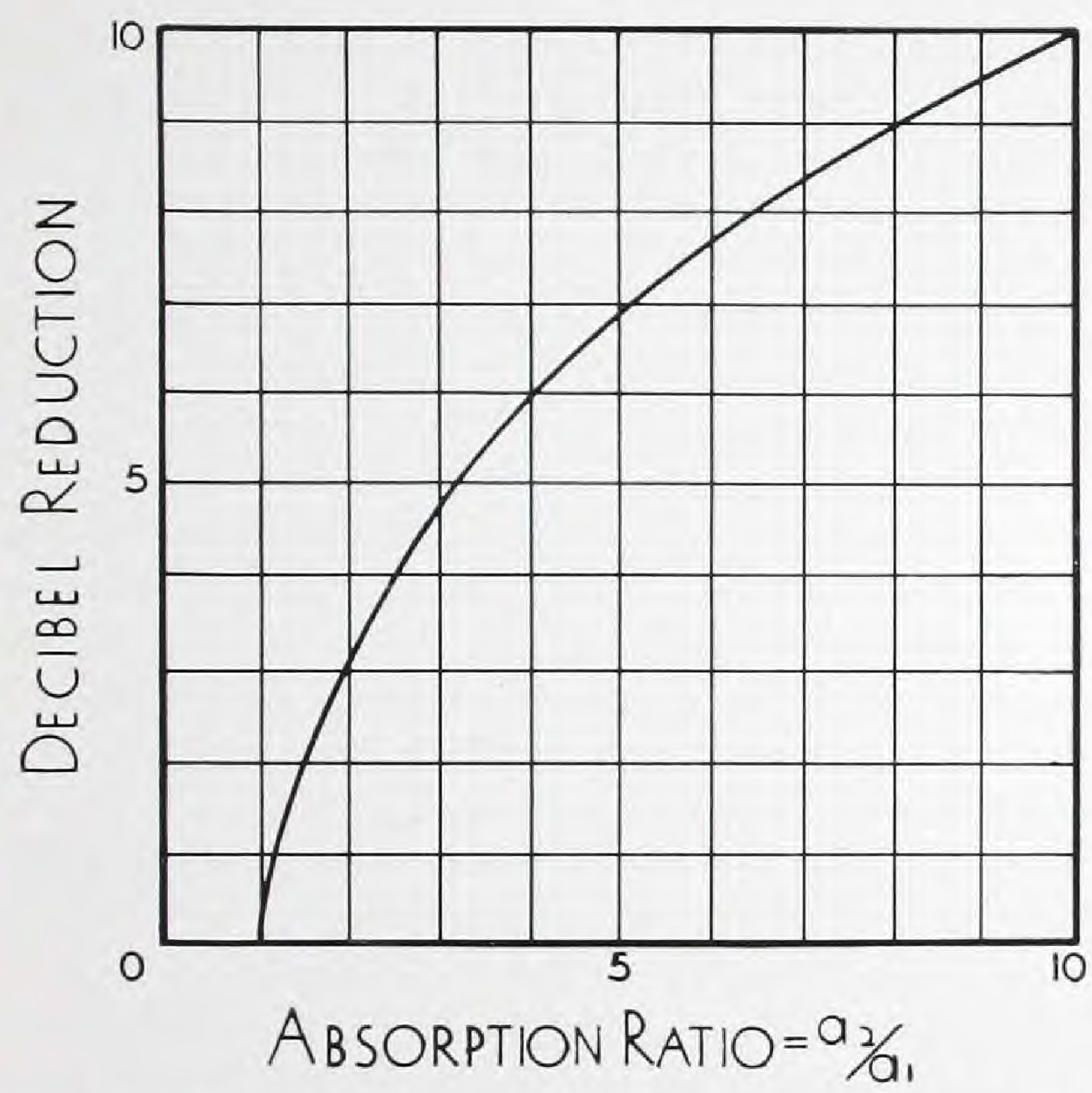


Fig. 2. Graph showing the relation of the decibel reduction to the ratio of the total absorption after treatment to the absorption before treatment

tion coefficient, and the sum of these plus the absorption supplied by furnishings and other objects gives the total absorption in the room. The following table gives the coefficients of materials commonly used as interior surfaces in offices.

Plaster, on tile, brick or concrete	.025
Plaster, on lath	.03 – .04
Concrete or terrazzo	.015
Linoleum, asphalt tile, or rubber tile	.03
Wood	.03
Glass	.03
Marble or glazed tile	.01
Carpet, unlined	.15–.20
Carpet, felt lined	.20–.35
Curtains	.10–.50
Chairs (each)	.2
Desks (each)	1.0

Reference to the loudness scale makes 5 or even 10 db. seem like a small reduction to be obtained by the addition of so much absorption. Practical experience, however, shows that reducing the loudness of noise in an office or factory by 5 db., at the average loudness level, causes a very appreciable decrease in annoyance.

From practical experience, 5 db. seems to be about the minimum reduction which should be attempted for acceptable results and because of the nature of the curve in Figure 2, it usually is not practical to attempt a reduction greater than 10 db.

Judgment of Relative Loudness

The explanation of the fact that a comparatively small decibel reduction produces a very substantial quieting effect lies in the manner in which the ear estimates reductions in loudness. The psychological sensation of loudness does not correspond directly to intensity level in decibels, but follows a rather complicated relation. For example, if a sound is reduced by only 6 db., it will be estimated as a reduction in loudness of 30 to 45 per cent, depending on the original level of the sound. This relation is shown in the chart of Figure 3.

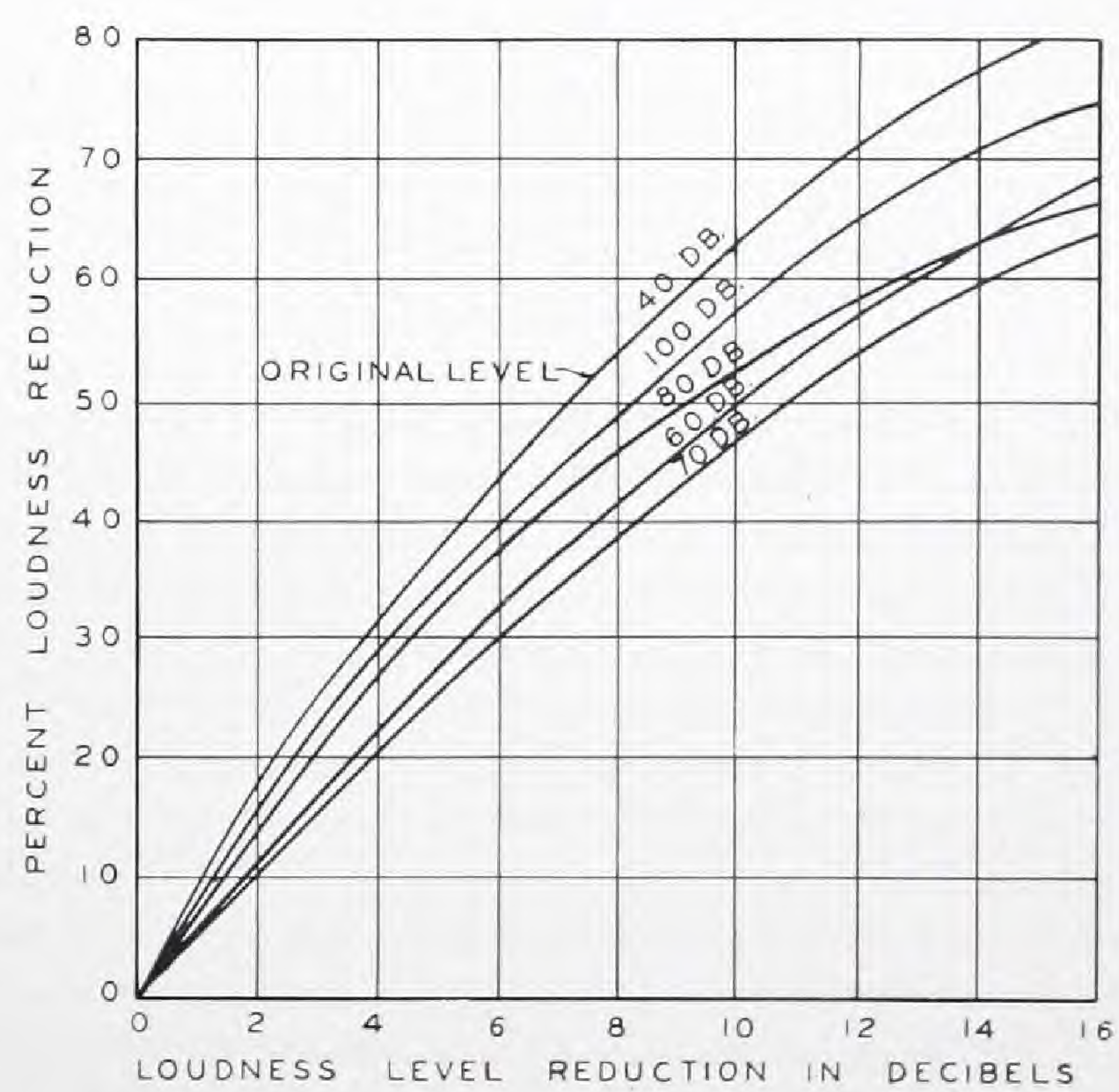


Fig. 3. Relation of loudness reductions as judged by the ear to decibel reductions for various original levels

These curves represent the average results of experiments in which a group of observers was asked to judge when one sound was one-half, one-fourth, three-fourths, etc., as loud as another.[1] (The term "loudness level" given in Figure 3 need not be defined here, but may be considered for practical purposes as equal to "intensity level.")

Noise Quieting Coefficient

Noise, as it is encountered in almost every case, contains a great number of frequency components which are spread over practically the entire audible frequency range. Specific noises, such as made by a telephone bell, or a ventilating fan, may be characterized by predominant high or low frequencies, but in general many such individual noise sources are present in a room along with a variety of noises having no characteristic frequency, such as traffic noise. Figure 4 shows the approximate frequency distribution of two common types of office noise.

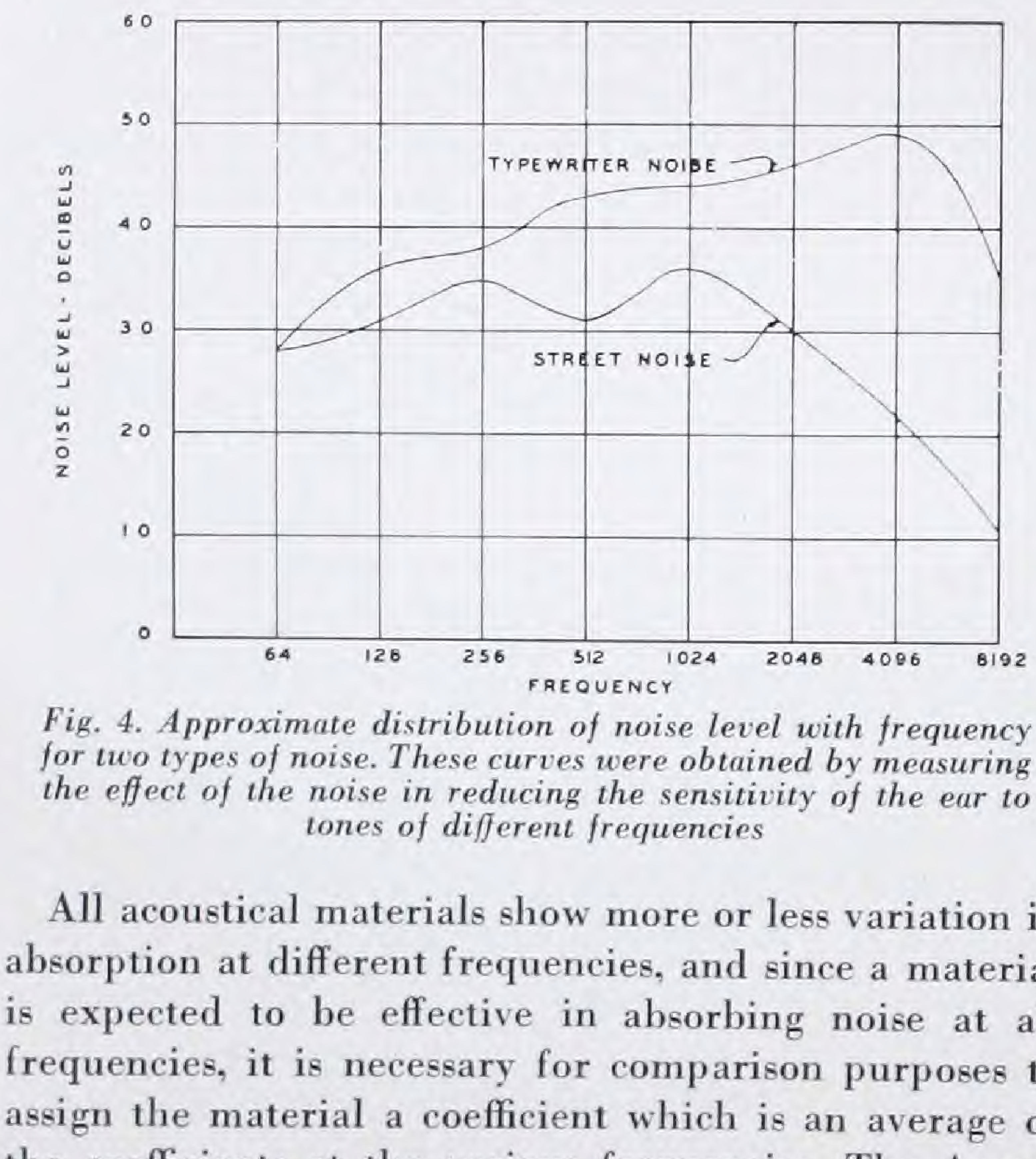


Fig. 4. Approximate distribution of noise level with frequency for two types of noise. These curves were obtained by measuring the effect of the noise in reducing the sensitivity of the ear to tones of different frequencies

All acoustical materials show more or less variation in absorption at different frequencies, and since a material is expected to be effective in absorbing noise at all frequencies, it is necessary for comparison purposes to assign the material a coefficient which is an average of the coefficients at the various frequencies. The Acoustical Materials Association has recommended that the average to the nearest 5% of the coefficients 256, 512, 1024, and 2048 cycles be used as a so-called "Noise Reduction Coefficient" for comparing the noise quieting values of materials.

It has become conventional practice to use this coefficient in calculating decibel reductions. It should be pointed out, however, that the reduction thus obtained is a purely mathematical quantity, and, due to the nature of the decibel scale, and to the fact that the frequency composition of actual noise varies widely between different times and locations, does not have an exact physical meaning which can be checked by actual measurement. The decibel reduction calculated in this way is, however, valid as an approximate measure for predicting the quieting effect which will be obtained, and for comparing different materials or different areas of the same material.

Practical Application of Principles

Since there are so many factors which have their influence in the degree of satisfaction attained by the use of absorption in quieting, it seems desirable to consider a few common problems met with in practice.

A person experiencing the effect of treatment in a large office may observe that the quieting effect is greater for distant noise sources than for those close at hand. This fact is at variance with the assumption implied in the idea of the decibel reduction, namely, that the noise from all sources is reduced by the same amount. The explanation for this discrepancy is as follows.

The decibel reduction formula is based on the assumption that the sound intensity due to a single source is the same at any distance from it. This is very nearly true in a room with all surfaces highly reflecting, and explains why noise seems to "spread like wildfire" through an untreated office. When a room is heavily treated, however, this condition is no longer true. Instead, a condition more similar to that outdoors, where the sound intensity decreases with increasing distance from the source, is substituted. In fact the outdoors is equivalent to a room in which all surfaces except the floor have an absorption coefficient of 100%, and this represents the limit in quieting which can be obtained by absorption.

This effect of decreasing noise level with distance from the source depends on the size and shape of the room and on the amount of absorption, being greatest for large, low rooms with heavily treated ceilings. In such rooms the actual noise reduction within a few feet of a noise source would be much less than the calculated reduction, and at considerable distance might easily be more than the calculated value.

For this reason the calculated decibel reduction in most rooms can not be accurately checked by actual measurement, but must be considered as a theoretical measure of the quieting effect obtained.

It is a commonly asked question whether the noise level existing in a room determines the amount of ab-

[1] Fletcher and Munson, "Loudness, Its Definition, Measurement and Calculation," Journal Acoustical Society of America, Vol. 5, No. 2, Oct., 1933.

sorption which should be added. This is only true when it is desired to reduce the noise to a definite level or where the initial level is so great as to make the maximum possible reduction desirable even though it may be costly. It would be most satisfying if, knowing the noise level at which annoyance starts, the noise in all offices could be reduced to that level. Unfortunately, however, the reduction possible with absorption is limited. It is apparent that an untreated room may be less noisy than a treated room and the unthoughtful person may complain of such a situation. The same person, however, will readily admit the relief of annoyance caused by the addition of absorption if he has experienced the conditions in the same room both before and after treatment.

One point, which is frequently misunderstood and may result in dissatisfaction, has to do with the effect of absorption on the distinctness with which sounds may be heard. In an untreated office, the highly sound-reflecting surfaces, in addition to building up sound intensity to an extremely high level, also cause excessive reverberation, or a prolongation of sound which often can be heard for several seconds after the actual source has ceased. In large rooms the overlapping and confusion of speech sounds caused by excessive reverberation, together with the interfering effect of the noise in the room, tend to make it difficult or impossible to understand speech except at close range. Acoustical treatment not only reduces noise but also decreases reverberation, and these combined effects of absorption may increase the ease with which speech is understood.

A case in point is a comparatively large room in which there is very little mechanical equipment and practically all of the noise enters the room from outside. The occupants of the room are more of the executive than the clerical type and their work requires the greatest privacy, consistent with the inability to provide private offices. The use of absorption in the room will reduce the loudness of speech but it will also reduce reverberation and, for most of the occupants, the noise from outside will be reduced more than the speech from other occupants, owing to the relative distance of the sound sources. The net result will be that the room will be generally quieter with the addition of absorption but the speech of one occupant will be more easily understood by another than before. It is evident that this whole condition might be changed if there were local noise makers, such as typewriters, scattered through the room to serve in masking the minimized speech from distant occupants.

The satisfactory reduction of noise in the small office is probably the most difficult room-quieting problem of the acoustical engineer. The occupant of the private office sits near the open window of his room, with whatever noise sources there are in the room close about him, and absorption placed on more distant walls or ceiling must be large in quantity and efficient to effect an appreciable reduction in the noises which disturb him. If the room is actually reverberant, then the addition of absorption has the relieving effect of apparently pushing away the sound source, but if the room is already sufficiently furnished to minimize reverberation, the ceiling, as well as a part of the walls, must be covered with absorption for satisfactory relief. The decibel reduction formula may be followed with safety provided it is understood that not too much is to be expected from very close noise sources.

The division of a large office space into smaller offices by the installation of partitions less than ceiling height is a rather common practice and the question is frequently asked whether use of a highly absorbent material over the entire ceiling will give the effect of privacy acoustically. The answer in general is "no." In most cases, even the entire removal of the ceiling would not prevent sound from one side being heard on the other side of the partition. The covering of a surface with an absorbing material having an absorption coefficient of .70 will reduce the level of the sound reflected from it just a little more than 5 db. In such a situation, the use of absorption is usually desirable to relieve the general noisiness of the office but it cannot be expected to increase privacy unless each office has its local noise maker as was mentioned in a previous example.

In the arrangement of offices, certain noise-making equipment is frequently segregated in a corner or wing of a large room and the question is asked whether treating the ceiling or walls near the machines will cause an appreciable relief from the noise they make. In a large office room with a comparatively low ceiling, the use of a small amount of absorption will give a localized quieting effect. The magnitude of this effect can best be approximated by forming a mental picture of the solid angle subtended at the source by the area treated, along with a consideration of the efficiency of the absorbing material used. In most cases the quieting effect will be very noticeable to the operators of the noisy machines, provided there are a number of them so that each operator may receive some relief from the noise of other machines because of the effect of absorption in reducing noise from distant sources. The noise will also be reduced for other workers in the large room who are not under the absorption. The quieting effect, however, will not be as great as if the entire ceiling were treated.

Acoustical Correction

In order for an auditorium to be satisfactory acoustically, for both speech and music, it is necessary that the separate speech sounds be sufficiently distinguishable to make speech clear and that the different component frequencies of music be preserved so as to be heard without distortion. The main factors influencing the acoustical condition of a room are reverberation, extraneous noises, loudness of the original sound, and the size and shape of the auditorium. Of these, reverberation is the main factor requiring adjustment in almost all cases, and since this factor is susceptible to a mathematical analysis, this discussion will deal mainly with it, although the other three factors will be given proper consideration.

Reverberation

When a sound is made in a room, the sound waves spread rapidly in all directions and strike the interior surfaces. If the surfaces are hard and have no ability to absorb sound, the waves are almost totally reflected. Ordinary interior surfaces, such as plaster, wood, concrete and glass, absorb less than 5% of the sound energy at each impact and the other 95% is reflected. It is evident that the reflection will continue back and forth between interior surfaces for a large number of times before enough energy is lost to make the sound inaudible.

The accumulation of these continued reflections is what is termed "reverberation." The effect of reverberation is to prolong a sound in a room after the actual source of sound has stopped. If the reverberation in a room is excessive, the trail of sound following one syllable of speech or tone of music will not die out before the next syllable is uttered. The result is quite obvious. There is a confusion of sounds in which nothing appears clear and distinct and audition is difficult and tiresome.

Method of Calculation

The first step in making an acoustical analysis of a room is to determine the reverberation time, defined as the time required, after the source is stopped, for sound to die out to one millionth of its initial intensity, or, in other words, for the intensity level to decrease by 60 db. The Sabine formula is usually used, taking its name from Professor W. C. Sabine of Harvard who developed it and was the pioneer worker in the field of architectural acoustics. This formula is written:

$$t = \frac{.05 \times V}{a}$$

"t" is the reverberation time in a room, in seconds, "V" is the volume of the room in cubic feet, and "a" is the number of absorption units present in the room. This unit will require explanation.

As previously stated, when a sound wave strikes an interior surface, part is reflected and part is absorbed, the amount absorbed depending upon the porosity and other characteristics of the material forming the surface. As a basis of calculation, the unit of absorption has been taken as one square foot of surface which absorbs all of the sound which strikes it, reflecting none. Such a surface is said to have a coefficient of 1.0 or an absorptivity of 100 per cent. A surface which absorbs one-fifth of the sound that strikes it has a coefficient of 0.20, and five square feet of such a material will be required to furnish one absorption unit. To determine the number of absorption units in a room, it is necessary to find the area in square feet of each of the component materials, and multiply each area by its coefficient. The sum of these products will be the absorption of the room. The following table taken from a publication of the Acoustical Materials Association, gives the coefficients at 512 cycles of the common materials used in building construction.

ABSORPTION COEFFICIENTS OF ORDINARY BUILDING MATERIALS, SEATS AND AUDIENCE

Brick wall, painted	.017
Same, unpainted	.03
Carpet, unlined	.15 – .20
Same, felt lined	.20 – .35
Fabrics, hung straight	
Light, 10 oz. per sq. yd.	.11
Medium, 14 oz. per sq. yd.	.13
Heavy, draped, 18 oz. per sq. yd.	.50
Openings	
Stage, depending on furnishings	.25 – .75
Deep balcony, upholstered seats	.50 –1.00
Grilles	.15 – .50
Plaster, gypsum or lime, smooth finish, on brick or tile	.025
Same, on lath	.03 – .04
Plaster, gypsum or lime, rough finish, on lath	.06
Glass	.03
Marble or glazed tile	.01
Wood panelling	.06
Floors	
Concrete or terrazzo	.015
Wood	.03
Linoleum, asphalt, rubber or cork tile on concrete	.03 – .08

INDIVIDUAL OBJECTS

Metal or wood chairs (units per seat)	.17
Auditorium chair, wood veneer seat and back	.25
Wood pews (per 18" length)	.4
Pew cushions (per 18" length)	1.45 –1.90
Theatre chairs, leatherette upholstered	1.6
Theatre chairs, heavily upholstered, plush or mohair	2.6 –3.0
Audience, per person	4.0

LESS NOISE-BETTER HEARING WITH PRESCRIBED SOUND CONDITIONING

It will be noticed in the table that the absorption of the audience, per person, is shown at 4.0 units, illustrating why the size of the audience is an important factor in determining hearing conditions in an auditorium. Auditoriums, which are acoustically poor when empty, are often satisfactory when filled, because of the large amount of absorption furnished by the audience.

In calculating the total absorption in a room, the absorption furnished by the seats is determined, but when the absorption of the audience is added, it is necessary to subtract the absorption of the seats occupied, as this is no longer effective. If the seats in an auditorium have a value of .25 units each, the net added absorption furnished by each member of the audience will be 4.0—.25, or 3.75 units.

In order to utilize the reverberation times obtained in calculation, it is necessary that we follow some standard and know what reverberation times have been found, by experience, to produce satisfactory hearing conditions. A detailed discussion of the most acceptable reverberation time will follow later in this article and at the present time we will assume that the values given in Figure 2 should be followed.

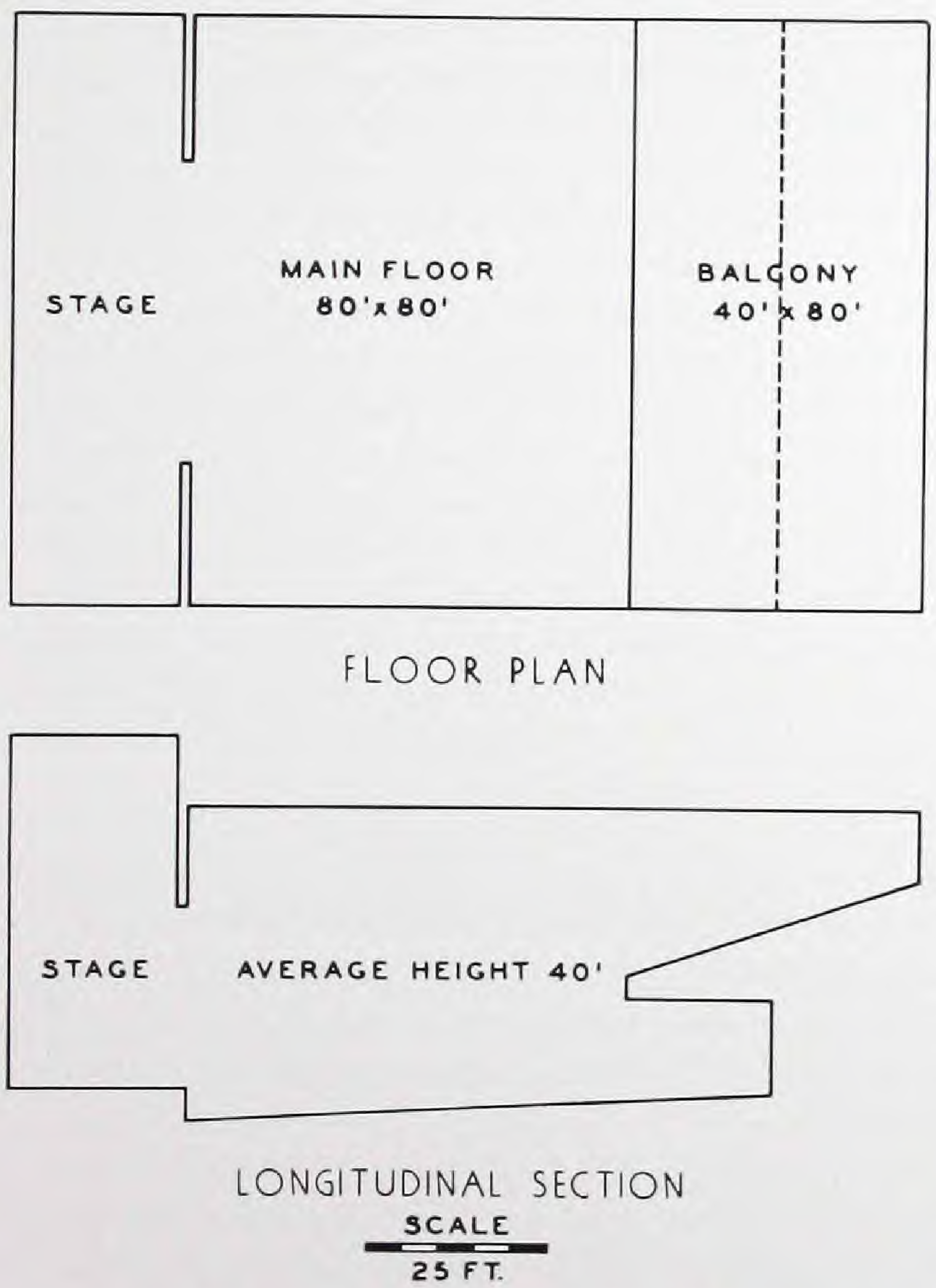


Fig. 1. Plan and section of a typical auditorium

A Typical Analysis

In order to explain fully the details of calculation, an analysis of a typical auditorium will be made in detail. We will take a room shown, in plan and section, in Figure 1, having a rectangular shape, a balcony, and a stage house. The main balcony floors are of concrete, the walls and ceiling are of plaster, the seats are wood veneer opera chairs, and the stage is furnished with a heavy velour curtain and average stage hangings. The volume of this room, exclusive of the stage, is approximately 260,000 cubic feet. Multiplying the area of each material by its coefficient gives the following result:

				Units
Main and balcony floors, concrete	9,600 sq. ft.	@ .015	=	144
Plaster ceilings	9,600 sq. ft.	@ .03	=	288
Plaster walls	11,800 sq. ft.	@ .03	=	354
Stage curtain and openings	800 sq. ft.	@ .25	=	200
Grille openings	100 sq. ft.	@ .50	=	50
Wood seats	1,500 sq. ft.	@ .25	=	375
Miscellaneous absorption[1]				50
Total absorption in empty room				1,461

In this example the volume of the stage is not included nor the absorption of the walls, floor and ceiling of the stage. The reason for this will be explained in detail later.

We will now calculate the reverberation in the room, empty, one-third full, two-thirds full, and with a maximum audience. Since one-third of the audience is 500 persons, the net added absorption will be (4.0–.25) or 3.75 units x 500 = 1875 units for each 500 people.

$$\text{Empty Room } t = \frac{.05 \times 260{,}000}{1461} = 8.9 \text{ seconds}$$

$$\text{500 Audience } t = \frac{.05 \times 260{,}000}{1461 + (500 \times 3.75)} = 3.9 \text{ seconds}$$

$$\text{1000 Audience } t = \frac{.05 \times 260{,}000}{1461 + (1000 \times 3.75)} = 2.5 \text{ seconds}$$

$$\text{1500 Audience } t = \frac{.05 \times 260{,}000}{1461 + (1500 \times 3.75)} = 1.8 \text{ seconds}$$

Figure 2 shows the acceptable range of reverberation time in a room of this volume is 1.2 to 1.65 seconds. The figures above show that, although hearing conditions may be fairly acceptable with extremely large audiences, the room is too reverberant with the smaller audiences for satisfactory audition. When there are only a few people in the room, it will be quite difficult to hear. Assuming that this room is used frequently with small as well as large audiences, it will be necessary to lower the rever-

[1]There is almost always present in a room a small amount of absorption not appearing upon the blueprints or readily apparent, but which should be allowed for in calculation. Window hangings in a school auditorium, apparatus in a gymnasium, statuary in churches, small quantities of carpeting and drapes are often present, but not always accounted for. The absorption to be allowed is a matter of judgment for which no set rule can be given.

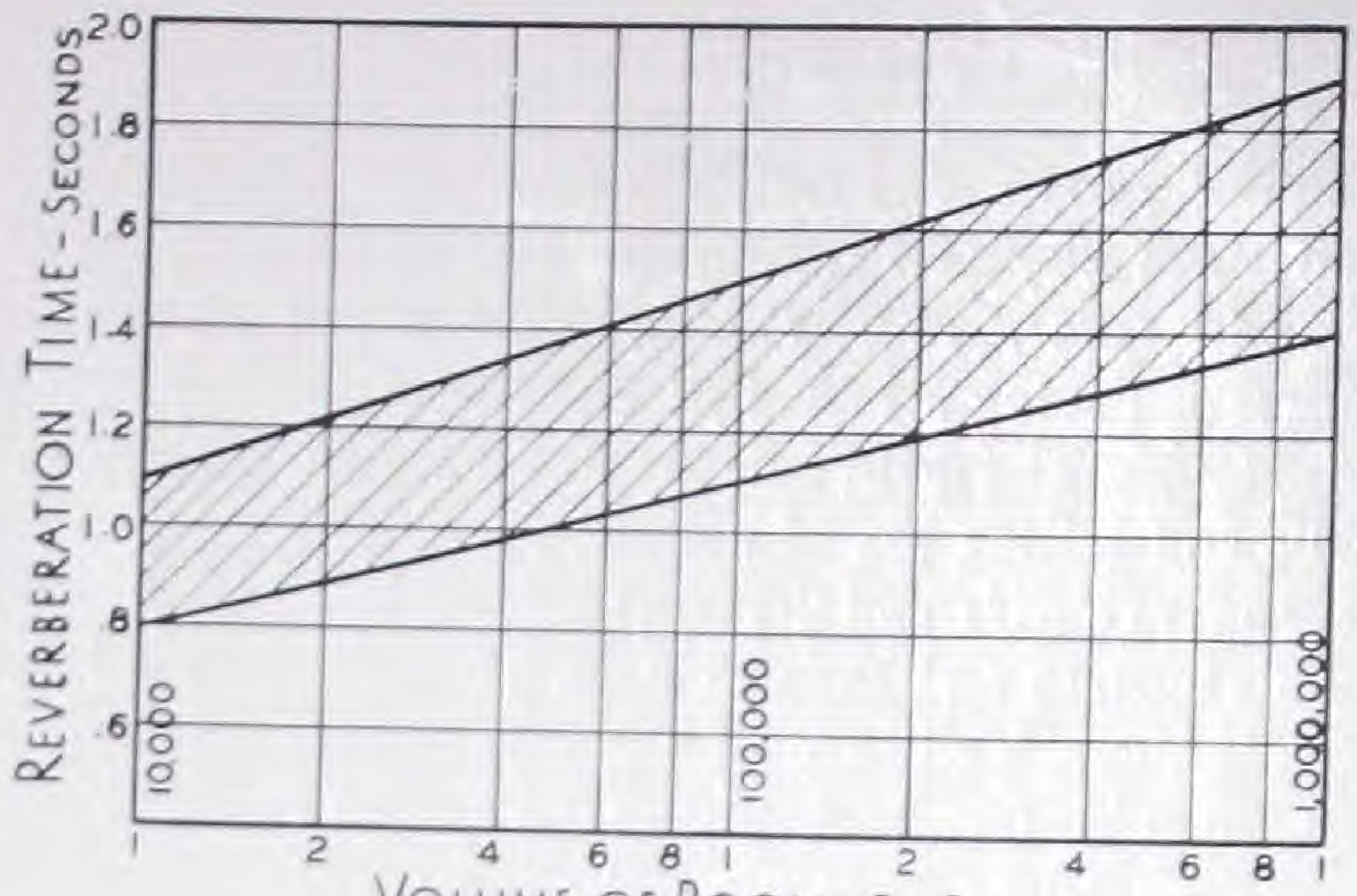


Fig. 2. Range of acceptable reverberation times for auditoriums of different sizes. The values shown refer to a frequency of 512 cycles per second

beration times to values which are close enough to the acceptable time for fairly good hearing conditions with all audiences.

Let us assume that it is desirable to reach a reverberation time of 1.6 seconds when the room is approximately one-third filled. We will now determine the number of units required to produce this acceptable reverberation time. Sabine's formula has been given as,

$$t = \frac{.05 \times V}{a}$$

but it may be written as,

$$a = \frac{.05 \times V}{t}$$

if for "t" we substitute the acceptable time of reverberation required, we will find the number of absorption units the room will need

$$a = \frac{.05 \times 260{,}000}{1.6} = 8120 \text{ units}$$

We already have present in the room 1461 units, and one-third audience will furnish 500 x 3.75 units = 1875 units, making the absorption in the room with a one-third audience, 3336 units. Since we need 8120 units, we must add approximately 4800 units in the form of an absorbent material.

A readily available area of treatment is present on the main ceiling, an area of 8000 square feet. If we use Type C-3 Acousti-Celotex, having a coefficient of .76 applied in panels totalling 6400 square feet, we will be able to obtain 6400 x .73 = 4672 sound-absorbing units. Since the Acousti-Celotex covers and renders ineffective the absorption of the plaster, we must subtract the absorption of the plaster from the Acousti-Celotex to obtain the net added absorption, .76–.03 = .73. We will now repeat the calculations for the reverberation in the room, adding the 4672 units, obtaining 1461 + 4672 6133 sound-absorbing units in the empty room.

$$\text{Empty Room } t = \frac{.05 \times 260{,}000}{6133} = 2.1 \text{ second}$$

$$\text{500 Audience } t = \frac{.05 \times 260{,}000}{6133 + (500 \times 3.75)} = 1.6 \text{ second}$$

$$\text{1000 Audience } t = \frac{.05 \times 260{,}000}{6133 + (1000 \times 3.75)} = 1.3 \text{ second}$$

$$\text{1500 Audience } t = \frac{.05 \times 260{,}000}{6133 + (1500 \times 3.75)} = 1.1 \text{ second}$$

The figures above show that the acceptable range reverberation times will be reached when the room one-third to two-thirds filled, so that good hearing co ditions will be obtained with the average audience. Ev when very small audiences are present, hearing con tions will be fairly acceptable. Although this room probably not in use a great deal with a capacity crow when it is, the reverberation will permit good auditio It is possible to vary slightly from the optimum reve beration range and still preserve good hearing cond tions.

It is often desirable or necessary to apply treatmen on both walls and ceilings or on walls alone. For ex ample, the 4800 units required in this problem coul have been obtained by applying 1360 square feet o Type C-4 Acousti-Celotex, having a net coefficient o .95 (.98–.03) on the rear walls above and below th balcony and 5200 square feet of Type C-2 Acousti Celotex with a net coefficient of .66, on available area on the side walls.

It can be seen that the relation between the volume of the room and the seating capacity influences the effect which the audience has upon the reverberation time. If the room is very large in comparison to the size of the audience, as in the case of many churches, the absorption of the audience plays but little part in reducing the reverberation, and it is necessary to add considerable acoustical treatment for acceptable hearing conditions. In other types of interiors, such as large halls with low ceilings, the size of the audience has considerable effect upon the reverberation time.

Acceptable Reverberation

There are a number of factors which govern the choice of an acceptable reverberation time for a given room. Such factors include the volume of the room, the effect of the audience in changing the reverberation time, the range of audience sizes for which good acoustics must be provided, and the use to which the room will be put, that is, whether for speech or music, or both, and whether for direct or reproduced sound, or both. In

general, a somewhat higher reverberation is desirable for music than for speech, for direct sound than for reproduced sound, and for organ, choral and heavy orchestral music than for solo and chamber music. However, in most rooms a variety of uses and audience sizes will be encountered. Moreover, considerable latitude in reverberation time is allowable without any noticeable effect on hearing conditions. For these reasons, the chart in Figure 2 shows a range of acceptable reverberation times, rather than a single value, for rooms of different sizes. The values shown refer to the standard frequency of 512 cycles per second, and may be used for any type of auditorium. For a given room an acceptable reverberation time should be chosen according to the probable use of the room as outlined above, and the correction should be worked out so that this time is obtained with an audience of the most probable size present. At the same time, the reverberation time for the empty room should be held below a certain upper limit in order to insure intelligibility of speech at all times. Experience, as well as tests on speech intelligibility, places this limit at 2.5 to 3.0 seconds.

Location of Treatment

In general, the reverberation time of a room is independent of the location of the acoustical treatment, provided the treatment is placed on areas accessible to sound waves, such as main ceilings and walls. Treatment applied on the rear portion of a deep under-balcony ceiling would not be entirely effective in reducing the reverberation in the main part of the room, since only a part of the sound waves would penetrate to this area. Such treatment is, however, very effective in quieting interfering noise, either from the audience itself or from foyers and lobbies.

Heavy treatment of rear walls, particularly in long, narrow rooms, is desirable in order to minimize echoes which would otherwise prove disturbing in the front part of the room. This is very necessary when the rear wall is curved.

Surfaces on or around stages should be reflecting rather than absorbent, so that they may reinforce and project the sound toward the audience. This is especially important to musicians, as it assists them in hearing the rest of the instruments in better balance with their own.

Side wall treatment in long, narrow rooms is often advisable, in order to prevent multiple echo or "flutter" between these surfaces.

Stages

In the preceding example we did not include the volume of the stage nor the absorption of the stage floor, walls, and ceiling in our calculations, because the volume of the stage was quite large in comparison to the size of the opening connecting it with the main auditorium. Such a small connection between the two large volumes does not allow sound to be reflected and absorbed in the same manner in the stagehouse as it is in the main auditorium. Frequently the stage curtain may be drawn, entirely excluding the volume of the stage, as when a speaker stands upon the stage in front of the curtain, or during a dramatic performance, the wings of the scenery and overhead drops tend to exclude the stage volume and absorption from that of the main auditorium. We merely give the entire opening a coefficient of from 0.25 to 0.50 depending upon the amount of absorption upon the stage and add this to the absorption of the auditorium. If the stage had been small, with no furnishings upon it and with a large opening, we would have included its volume and absorption in the general calculations.

Reverberation at Different Frequencies

All absorbing materials, including an audience, have different coefficients at different frequencies, and therefore the reverberation time of room will vary with the frequency. It has been found by experience however, that the reverberation time at the single frequency of 512 cycles serves in most cases as a satisfactory measure of the quality of hearing conditions. This frequency has been adopted as common practice because it is at the middle of the range of frequencies covered in acoustical measurements, and because most of the data on acceptable reverberation times have been based on this single frequency.

In most cases, absorption of the audience furnishes such a large part of the total absorption that the reverberation-frequency characteristic of an auditorium is not altered to any appreciable extent by the introduction of acoustical treatment. However, in rooms where the treatment supplies most of the absorption, it is possible for reverberation to be excessive at other frequencies, particularly low frequencies, even though the reverberation time at 512 cycles is adjusted to the acceptable value.

It will be noted in the table of coefficients of Accousti-Celotex that Types C-1 and C-2 have much greater absorption at low frequencies when mounted on furring than when cemented to a solid backing. In cases where high absorption at the low frequencies is desirable, it is recommended that these types be used and applied on furring.

General Reverberation Formula

The Sabine formula, $t = .05V/a$, is sufficiently accurate for analysis of most types of audience rooms. For "dead" rooms, that is, rooms having a reverberation time of less than 1 second, it has been shown that reverberation times calculated by this formula are considerably high, and that the general reverberation formula, developed by Eyring and others, is more accurate. This formula is written

$$t = \frac{.05V}{-S \log_e (1 - a)}$$

where "S" is the total surface area in the room, and "*a*" is the average coefficient of absorption, obtained by dividing the total area "S" by the total absorption "*a*." An approximation to this formula which simplifies calculation may be written

$$t = \frac{.05V}{a} - \frac{.027V}{S}$$

This is simply the Sabine formula, minus a correction $.027V/S$ which is constant for any given room and does not depend on the absorption or on the frequency. It is recommended that this formula be used in analyzing radio studios or other rooms with reverberation times less than 1 second.

Shape and Distribution

At the beginning of this discussion it was mentioned that there are four major factors in determining the acoustical condition of an auditorium. Because the factor of reverberation is usually the most important consideration, this subject was discussed in detail first. It is also necessary to consider the problem of sound

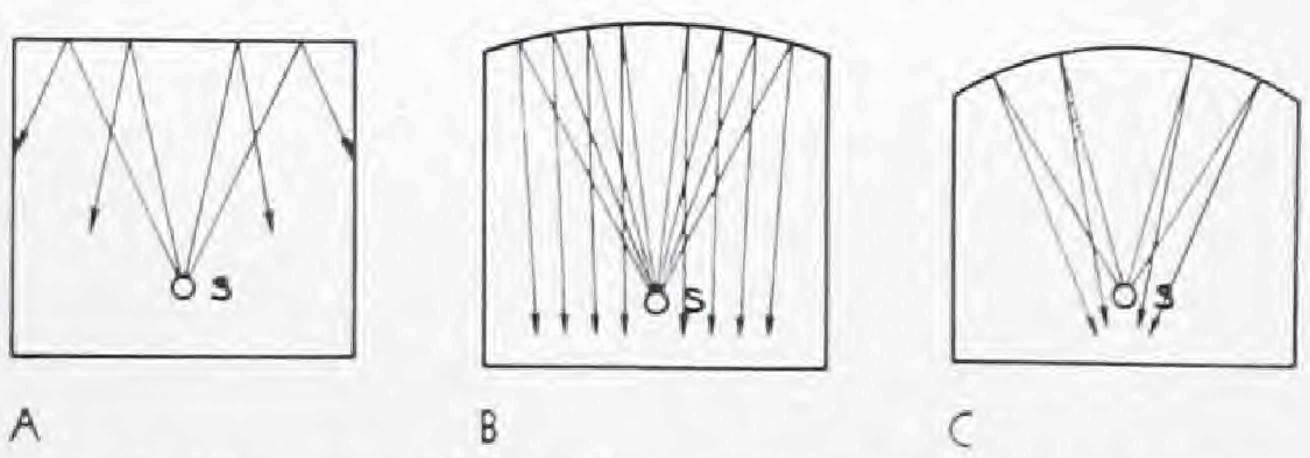


Fig. 3. How sound is reflected from surfaces of different curvature. (A) Divergent reflection from a flat surface is generally most desirable. (B) Parallel or slightly convergent reflection may sometimes be advantageous, but is often undesirable. (C) Sharply focused reflection causes bad echoes and sound concentrations.

distribution, which is mainly affected by the shape of the auditorium.

In general, a room of rectangular shape is desirable. Large curved surfaces should usually be avoided as they have a tendency to focus sound in the same manner that a curved mirror focuses light. An even distribution of sound throughout an auditorium is desirable, so that any surface which concentrates sound in one portion of the room at the expense of another is to be avoided. In certain cases, such as a high curved ceiling or a curved rear wall in a long room, this focusing action may be such as to cause an abnormally loud and distant echo, which may interfere seriously with hearing. Figure 3 shows how sound is reflected from surfaces of different curvatures. In general, the radius of curvature of a ceiling should be less than half or more than twice the ceiling height, and the same rule applies to a rear wall with respect to the length of the room. The best cure for difficulties due to curved surfaces is to change the radius of curvature in accordance with the above rule, but where this is impossible, the intensity of reflections from such surfaces may be reduced by treating them with highly absorbent material.

Whispering Galleries

The startling acoustical effects observed in whispering galleries are due to curved surfaces which are so situated as to cause extremely sharp focusing action. In such rooms, most of the sound radiated from the source is reconcentrated into a small focal region, and if the observer's ear is located in this region, the sound will appear much louder and closer at hand than at any other point in the room.

This frequently leads to the widespread but erroneous belief that rooms having these unusual characteristics are acoustically excellent. As a matter of fact, the opposite is more often the case, since the concentration of sound at the focal point is offset by a loss in intensity at all other points. Moreover, the room may be excessively reverberant, in which case hearing would be poor regardless of focusing effects. A case in point is the Mormon Tabernacle at Salt Lake City. This room has a rather famous whispering gallery effect, but studies have shown that actually it is acoustically poor for speech over most of the seating area unless the room is well filled and electrical voice amplification is used.[2]

Balconies

Poor hearing conditions are often encountered in under-balcony spaces. The opening to the under-balcony space should naturally be as large as possible to allow sound to enter. A low, deep balcony is undesirable because the low opening does not permit sufficient sound intensity in the rear portion of the space for satisfactory hearing conditions. The accompanying illustration in Figure 4 shows how an under-balcony space receives only the direct sound in the angle "a,"

[2]Hales, "Acoustics of the Salt Lake Tabernacle," Jour. Ac. Soc. Am., Vol. I, No. 2, Jan., 1930.

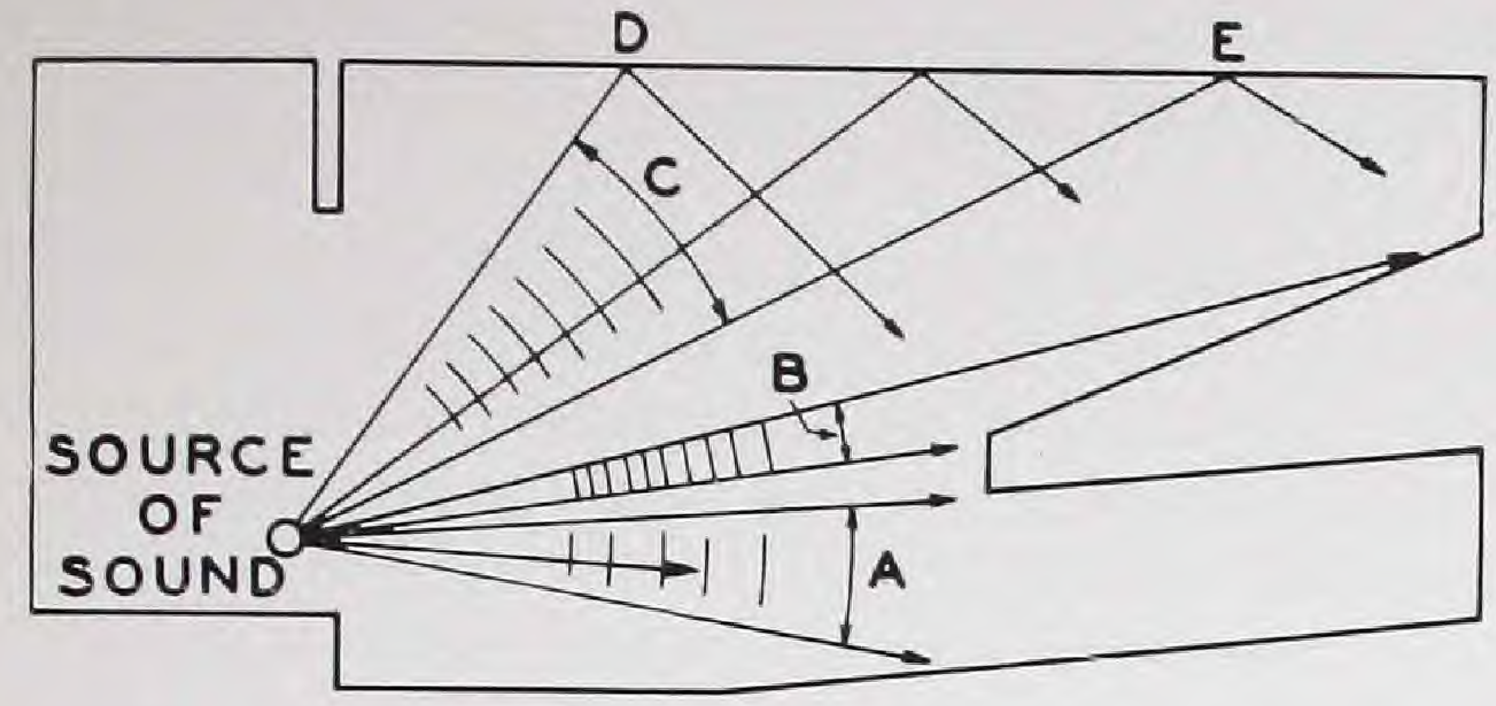


Fig. 4. Sound distribution above and below a balcony

without the benefit of any helpful ceiling reflections. The balcony portion of the room, while only receiving the direct sound contained in angle "b," receives from the ceiling all sound which is reflected from "d" to "e," or the entire angle "c."

Loudness and Noise

Another consideration in the acoustical condition of an auditorium is the loudness of the original sound. It has been found that the intelligibility of speech is directly related to the loudness. A person with a loud voice is heard better than one with a weak voice, so that in large auditoriums it is often desirable to use a good public address system to amplify the voices of weak speakers. Of course, it is necessary that the reverberation in the room be acceptable, or amplifying the sound would only increase the reverberation effects, thus usually being harmful, rather than beneficial, to the hearing conditions. The amplifying equipment must be of good quality, or the distortion introduced will overcome the benefits of amplification.

Noise also plays a part in the quality of the hearing conditions in a room, though an entirely negative one. The presence of extraneous noises means that the original sound must be increased in loudness to overcome the effects of the interference, and that the listeners must concentrate on the original sound to effectively exclude the extraneous noise from their consciousness. Noises are often low pitched in character and have the property of effectively masking the higher pitches. Although the volume of sound in speech is contained in the lower frequency components, the intelligibility is largely in the higher frequencies, so that any masking of these upper frequencies decreases greatly the ability to interpret the speech. While the primary purpose of installing an acoustical material in an auditorium is to decrease reverberation, such treatment also tends to quiet and lessen the annoyance from extraneous noises.

Noise sources in auditoriums, such as ventilators, machinery, adjoining noisy rooms, etc., may be quieted at their origin, thus reducing the interfering effect. Absorption in ventilation ducts, absorbent housings for machines, and anti-vibration platforms under them, and the use of absorption in corridors and lobbies is advantageous.

Wires and Sounding Boards

In spite of the widespread knowledge of the established principles of acoustical correction, one frequently encounters theories that are either inaccurate or entirely fallacious. One of these, which has no known origin, but a particularly tenacious life, has to do with the stretching of wires across an auditorium. It is not known whether these wires are intended to absorb or to amplify sound, and no data are available as to the number of wires, their thickness, and the tension necessary to produce the desired results. However, auditoriums are occasionally seen having from three or four up to hundreds of wires strung between the upper walls. By consulting the known laws of sound and vibration, or by actual observation, one can easily satisfy himself that such treatment has no discernible effect on the acoustics of a room. Improvements claimed are either imaginary, or are due to the reduction of reverberation caused by the unusually large audience which has gathered to witness the effect of the wires.

Another scheme which has a legitimate scientific basis, but is often erroneously applied, is the use of sounding boards, that is, large plane or curved reflectors placed over the head of the speaker. When properly used a sounding board tends to reinforce the sound of a speaker's voice, and therefore may be useful in very large rooms where it is difficult to make the voice carry to the farthest corners. However, as discussed previously in connection with loud speakers, increasing the loudness may do more harm than good if the reverberation is excessive, and it is this mistake that is frequently made in the use of sounding boards.

Radio Studios

IN designing the acoustical treatment for a radio studio, very exacting requirements must be met. It is necessary that the acoustical conditions be such that it form a nearly perfect link in the chain of the transmitting system, which should allow the distant listener to hear the components of the reproduced sound with the same relative intensity as if present at the source of sound. This necessitates careful adjustment of the acoustical condition of the broadcasting studio, which involves primarily securing the proper reverberation time, the proper distribution and type of absorbent furnishings, and a studio of suitable shape and size.

Studios should be generally rectangular in shape, and of a size adapted to the volume of sound generated, i.e., varying from a small studio for solo performances to large, high rooms for concert orchestras. The ceiling height should not be too low in the larger studios, but should range in general from about 10 feet in the small 15 x 20-foot solo studio to about 25 feet in the 40 x 70-foot concert rooms.

It is necessary to provide adequate sound insulating construction to prevent interference from other studios and from outside noise. Best results are obtained with concrete floor and masonry wall construction as a base, with the finished floor, wall and ceiling structurally isolated by means of resilient mountings and suspensions. Where this is impractical, good results can be obtained with lighter construction employing Celotex Building Board, Celotex Cemesto Board, or Thermax.

For entrance doors, the best sound insulation is obtained with two sound-proof doors separated by a small vestibule. Next in order of effectiveness, are double soundproof doors immediately adjacent and a single soundproof door. Whatever doors are used should be of heavy construction and should be fitted with gaskets and threshold closers so as to form an airtight seal around all edges. Observation windows should be of heavy double or triple panes, each one set in felt or rubber and if possible in separate frames isolated from each other.

The ventilating system should be designed in such a way that the distance by way of the ducts between any two studios is as long as possible. Lining the ducts with acoustical treatment is recommended to prevent the transmission both of air noise and sound between studios. The ventilating fan should be mounted on a vibration isolating base and the outlet should be connected to the duct system by a canvas or other flexible coupling.

The proper distribution and type of absorbent furnishings involves placing acoustical materials so that all of the surfaces, or at least opposite parallel surfaces, have approximately the same degree of absorption.

If the studio has a padded carpet on the floor, a highly absorbent material upon the ceiling, and hard, non-sound absorbing walls, the sound waves between the floor and ceiling will die out very quickly, while the sound waves between the walls will continue to be reflected, producing a "flutter" or "rattle" of sound which will interfere with good broadcasting. Such a condition may exist if an undraped door and window or two hard plaster panels are opposite and parallel. To avoid this the wall area is generally finished in a material of medium absorption, while the ceiling treatment is dependent upon the type of floor covering. If wood, rubber tile, or linoleum is used, a material of high efficiency is placed upon the ceiling to compensate for the low absorption of the floor, while, with carpeting it is only necessary to use a material of medium absorption.

Studios and other rooms where sound is transmitted by a microphone require somewhat lower reverberation times than rooms intended for direct listening only. Figure 1 shows the optimum reverberation times at 512 cycles of studios of different volumes as recommended by the National Broadcasting Company on the basis of their experience.

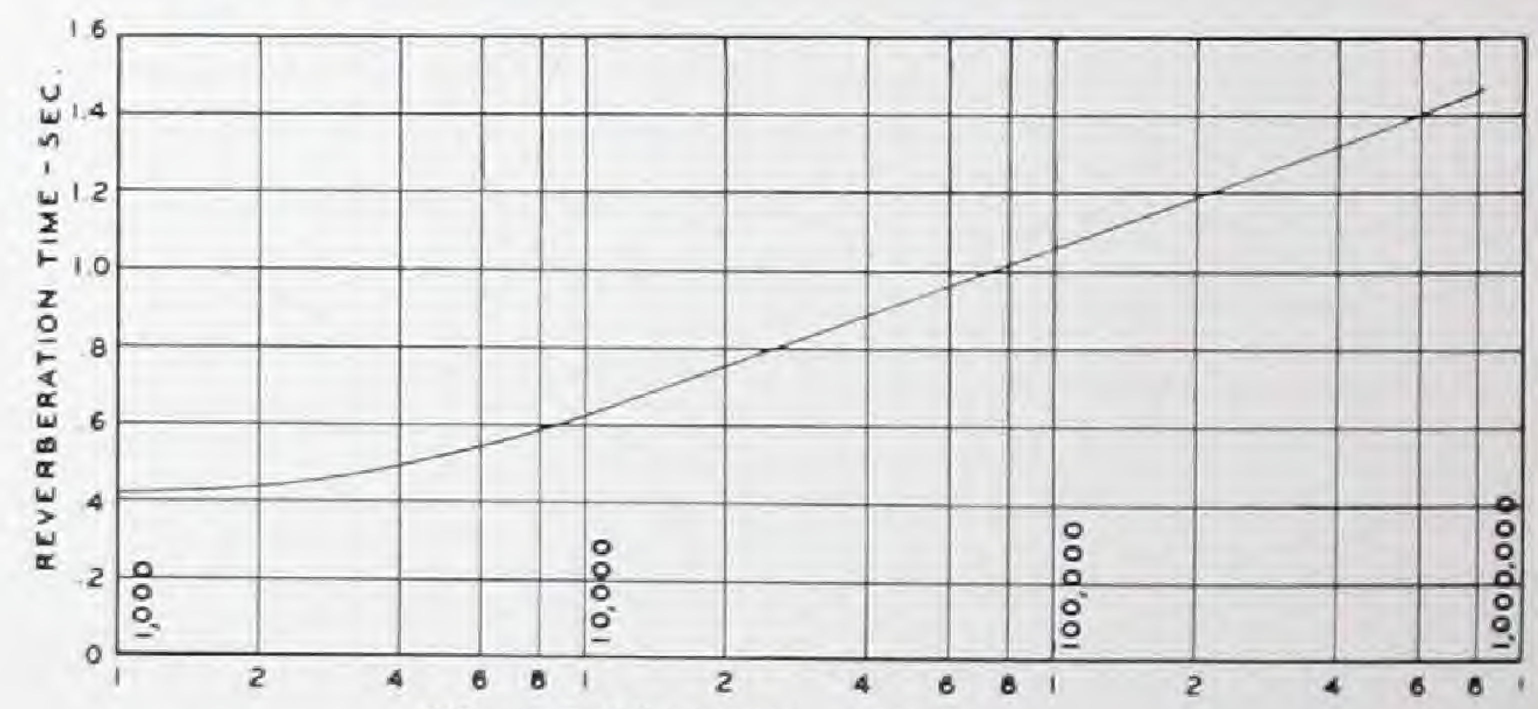


Fig. 1. Optimum reverberation time at 512 cycles of studios of different volumes, as recommended by the National Broadcasting Company

Consideration must also be given to the reverberation times at other frequencies than 512 cycles, particularly the lower frequencies. The National Broadcasting Company has also developed the optimum reverberation frequency characteristic shown in Figure 2. This curve shows the relation of the optimum reverberation time at all frequencies to the optimum time at 512 cycles. The values shown in the curves of Figures 1 and 2 are by no means critical, and slight departures from these values will have no noticeable effect on acoustical conditions.

Recent improvements in and additions to Celotex

acoustical products have made them particularly suitable for use in studios. Types C1 and C2 Acousti-Celotex applied on furring strips and Type A Absorbex and Calicel over mineral wool, show remarkably high absorption at the low frequencies in comparison to the higher frequencies. Since it is usually desirable to cover all wall and ceiling areas, and since the use of these materials alone generally provides more absorption than

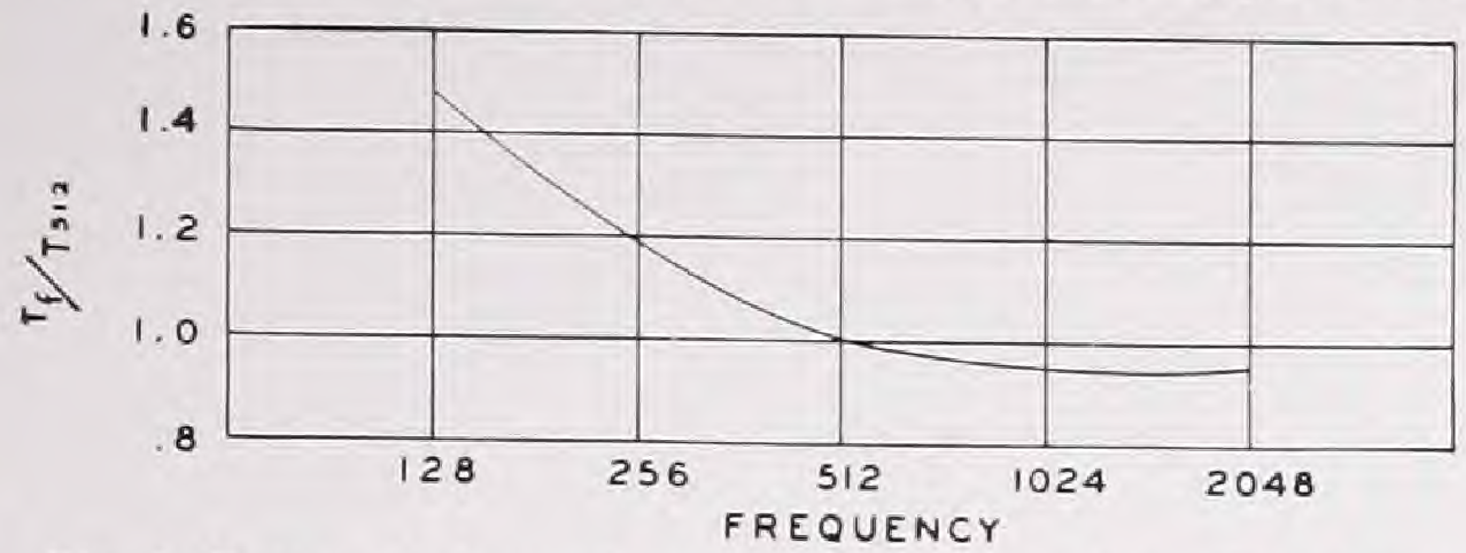


Fig. 2. Ratios of the optimum reverberation time (T_f) at any frequency to the optimum at 512 cycles (T_{512}), as established by the National Broadcasting Company

is necessary, part of the available areas are usually covered with Celotex Building Board or Acoustical Tile Board, also applied on furring. These materials have rather low absorption coefficients, but show remarkably uniform absorption over the frequency range. Celotex Acoustical Tile Board, nailed to furring, has the following coefficients as measured at the Riverbank Laboratories:

Thickness and Finish	Frequency				
	128	256	512	1024	2048
½", unpainted	.31	.33	.29	.26	.26
⅝", painted	.26	.42	.11	.09	.12

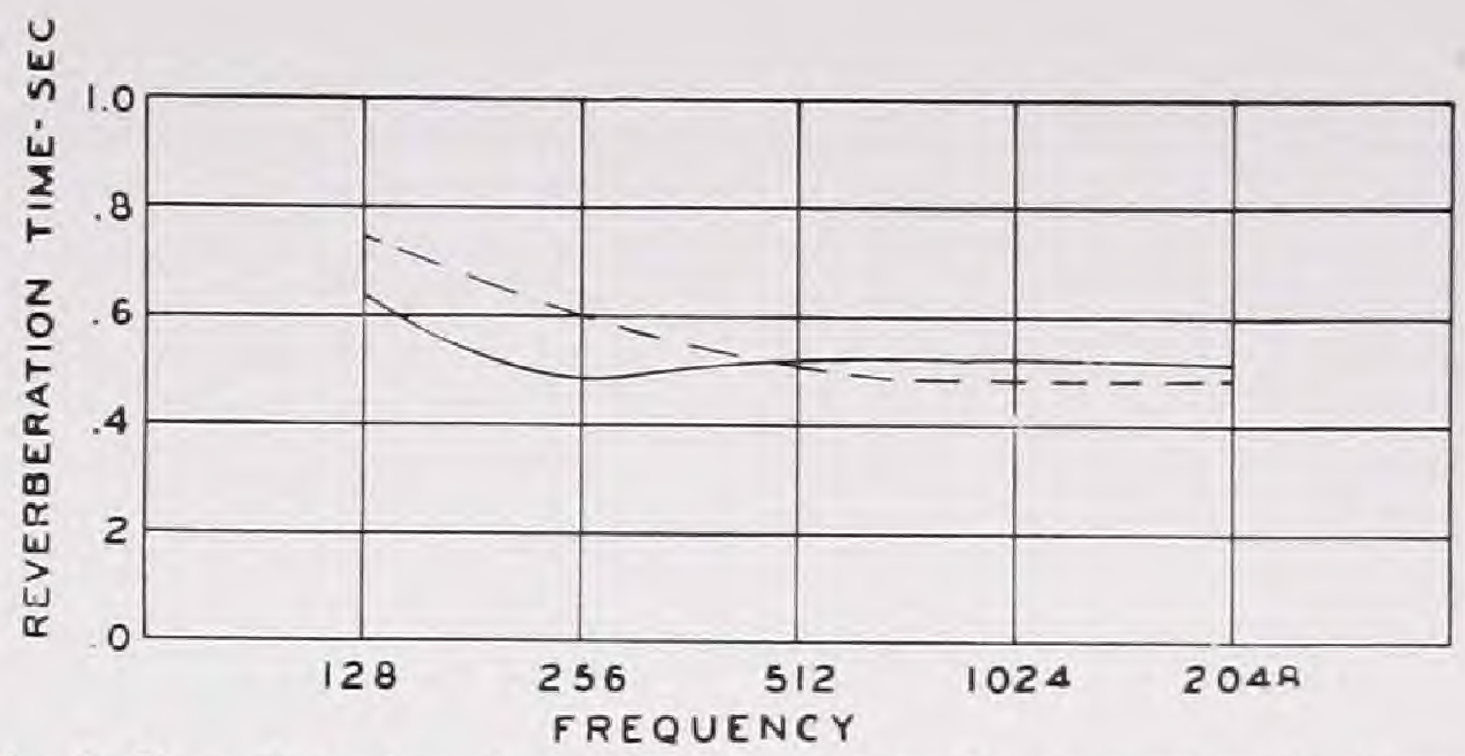
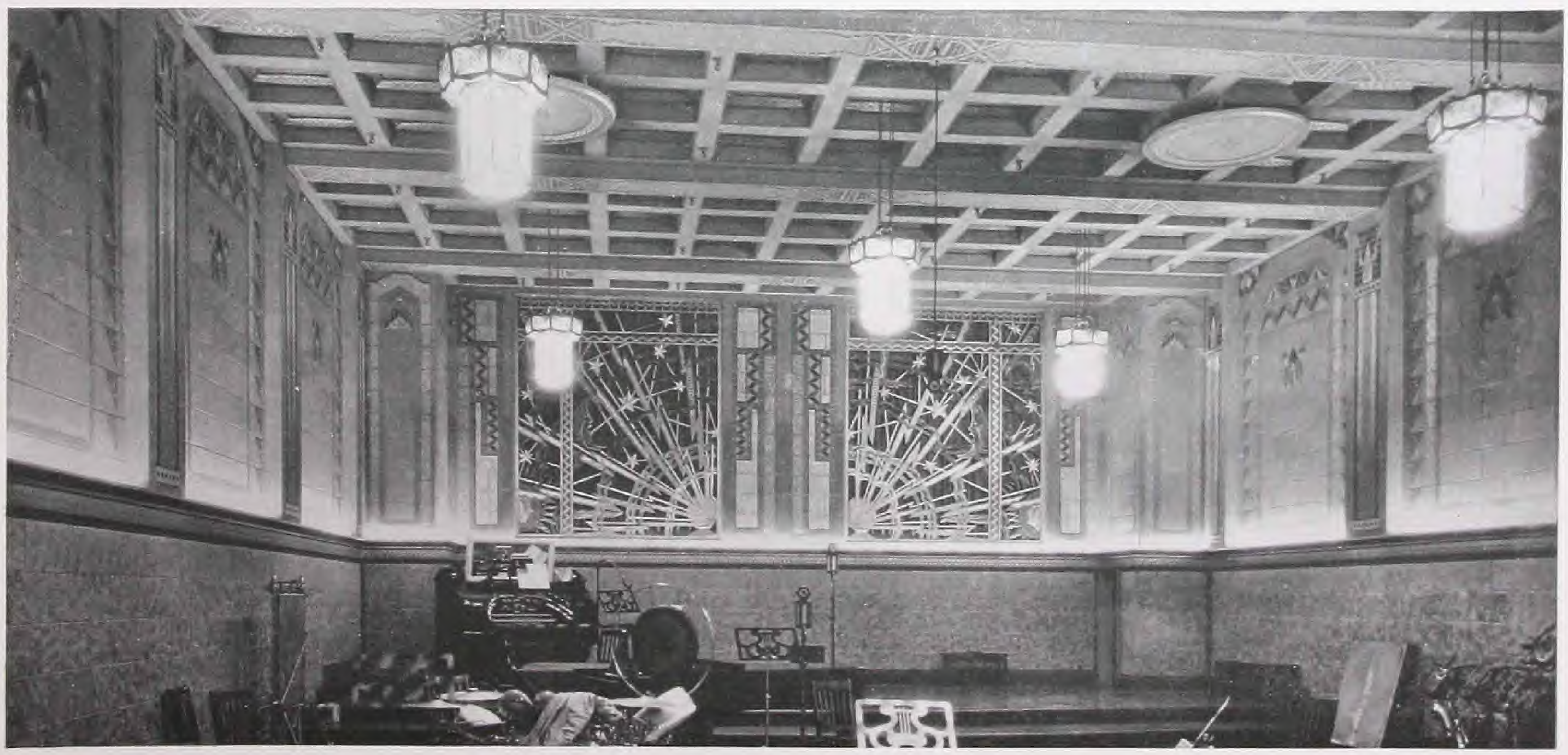


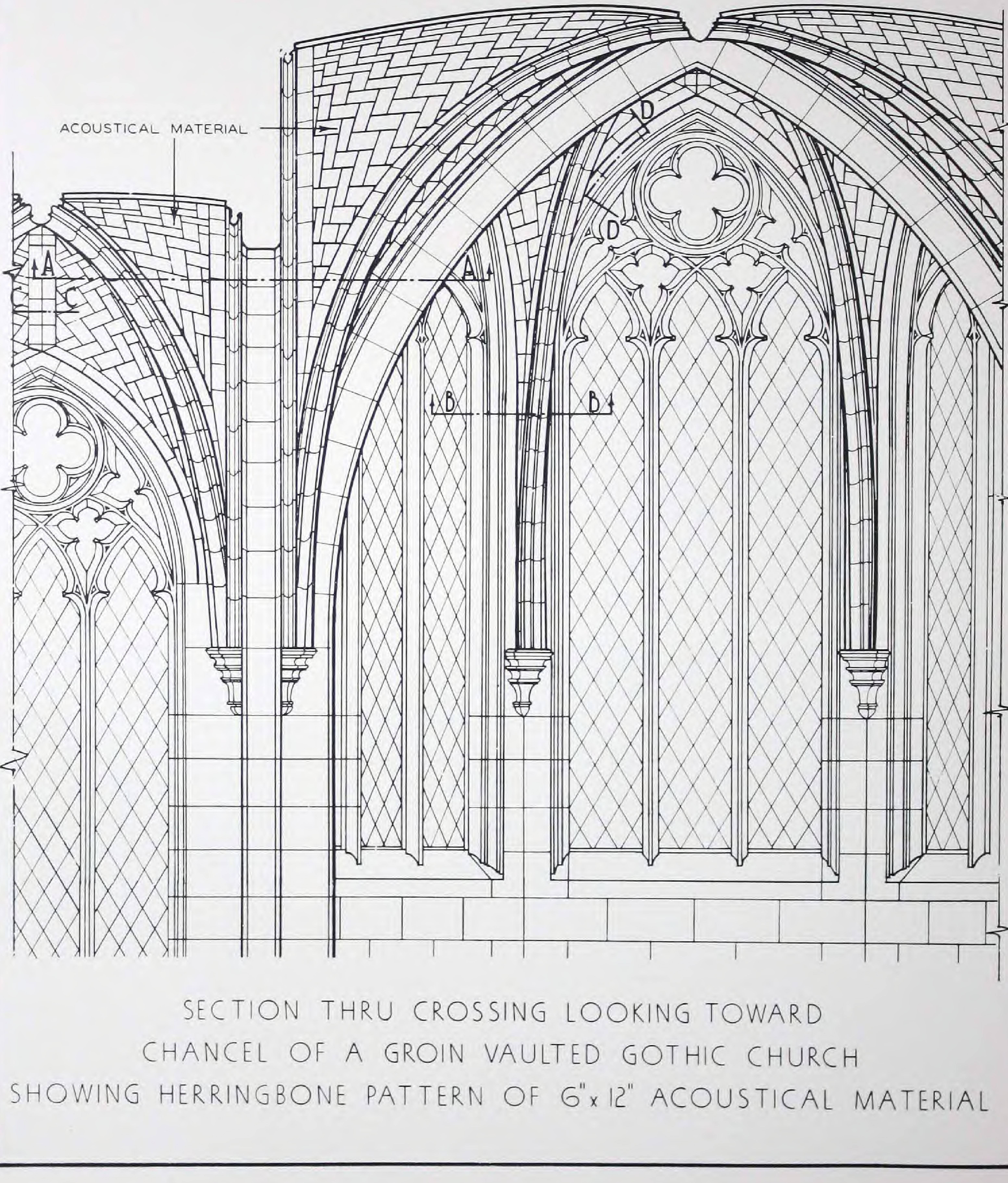
Fig. 3. Reverberation times of a typical studio treated with Acousti-Celotex and Celotex Tile Board (solid line), compared with the optimum reverberation-frequency characteristic (dotted line)

By combining Celotex Standard Board or Tile Board with Acousti-Celotex it is possible to obtain reverberation times closely approximating the optimum values at all frequencies. The graph in Figure 3 shows the reverberation-frequency characteristic of a typical studio treated with a combination of Types C-1 and C-2 Acousti-Celotex and Celotex Tile Board, all applied on furring. The solid curve represents the calculated reverberation times obtained with this treatment, and the dotted curve is the optimum reverberation-frequency characteristic recommended by the National Broadcasting Company.

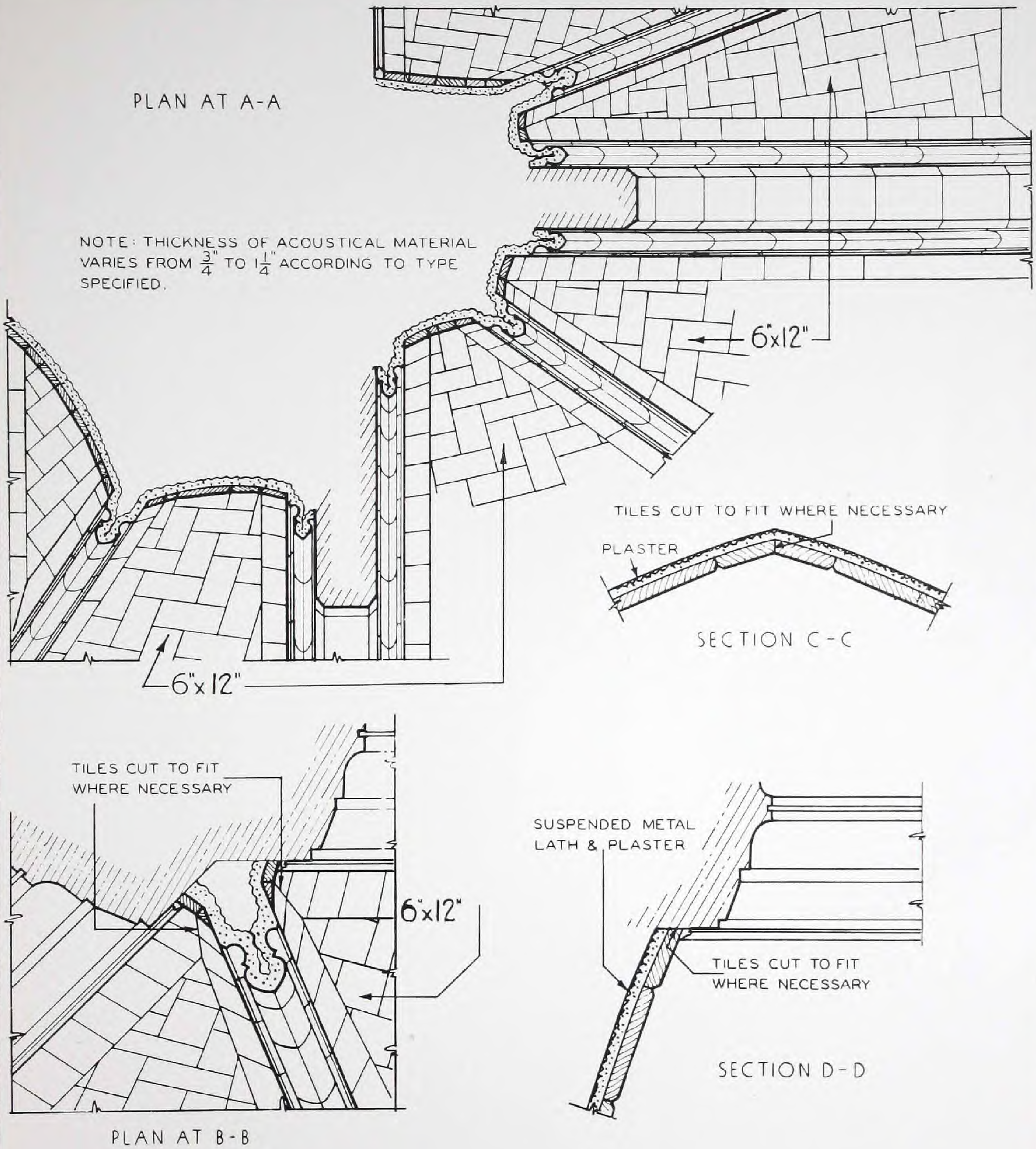
Excellent acoustical conditions for studios may also be obtained by the use of Vibrafram, a Celotex acoustical product which absorbs sound by diaphragmatic vibration instead of by porosity. Vibrafram has a nearly flat absorption-frequency characteristic, with somewhat higher absorption at the low than at the high frequencies. It is therefore useful either alone or with other types of treatment for obtaining the desired reverberation times over the entire frequency range.



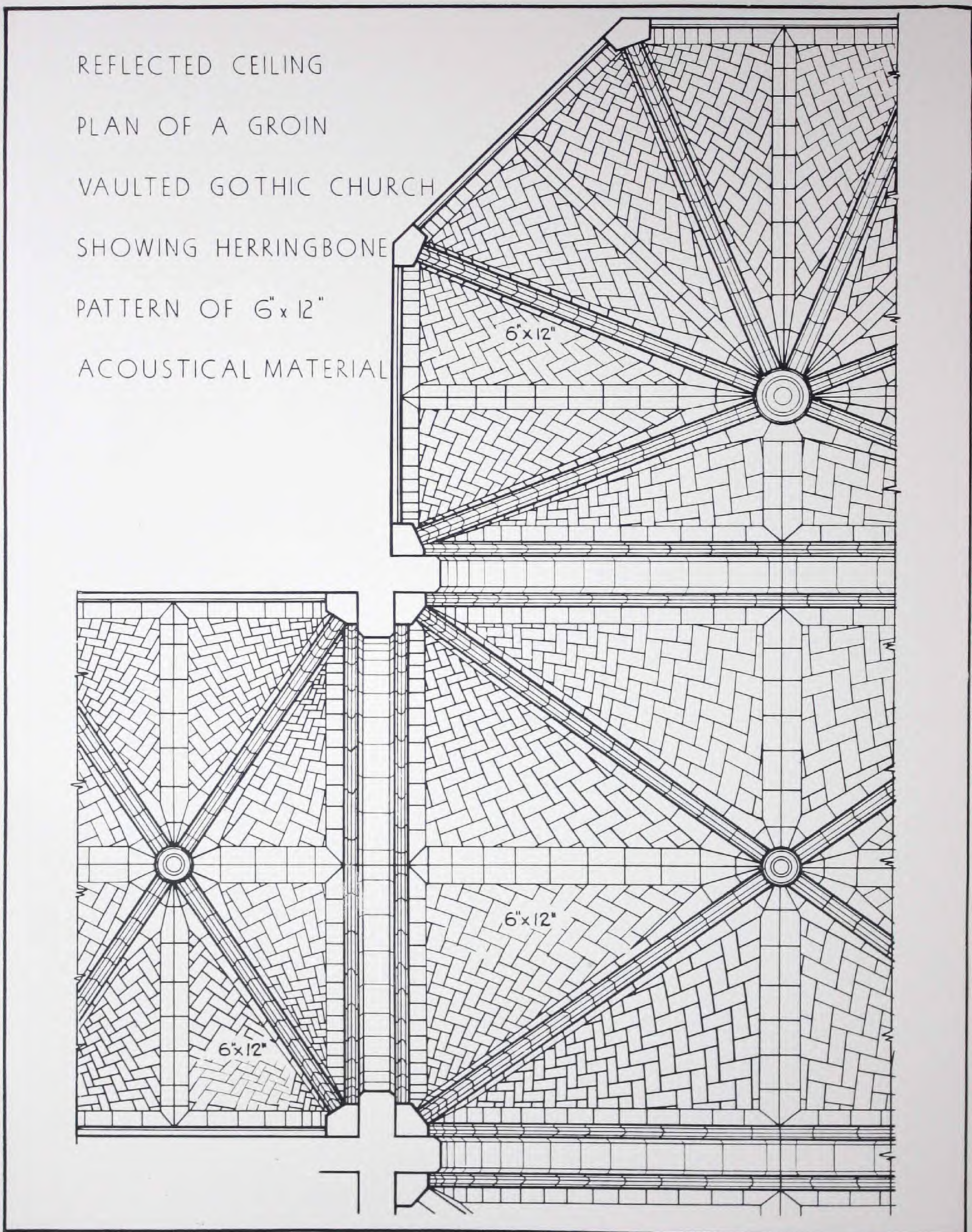
Station WLW, Cincinnati, Ohio—Acousti-Celotex



SECTION THRU CROSSING LOOKING TOWARD
CHANCEL OF A GROIN VAULTED GOTHIC CHURCH
SHOWING HERRINGBONE PATTERN OF 6"x 12" ACOUSTICAL MATERIAL



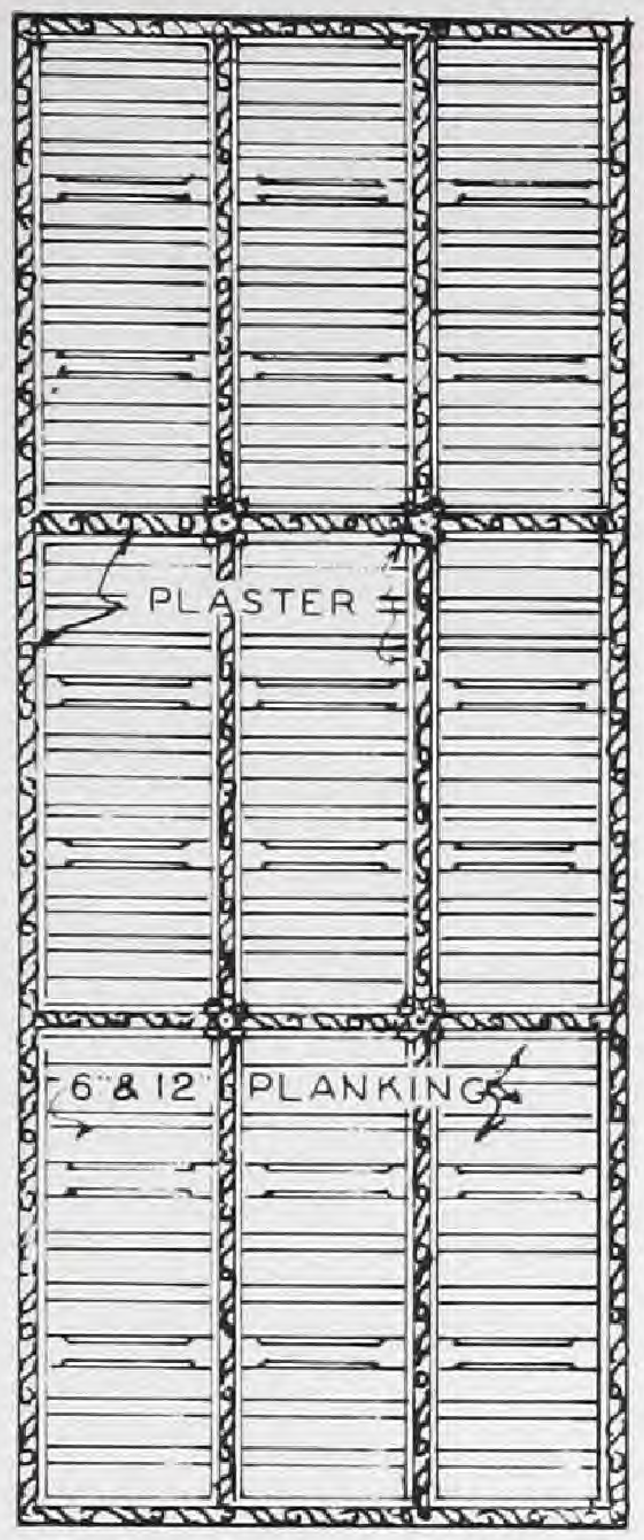
DETAILS SHOWING APPLICATION OF
ACOUSTICAL TILE TO A GROIN VAULTED CEILING



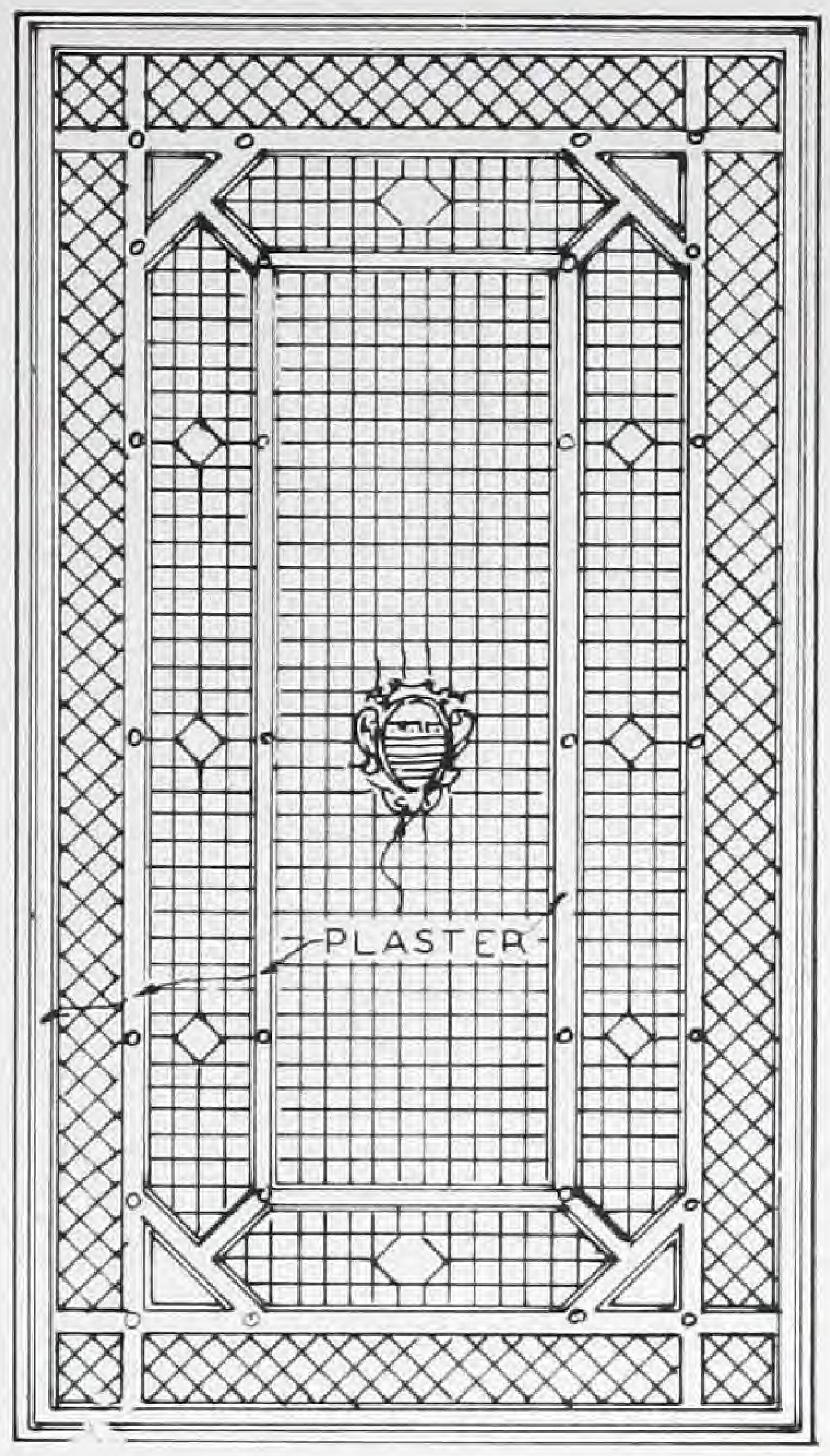
REFLECTED CEILING PLAN OF A GROIN VAULTED GOTHIC CHURCH SHOWING HERRINGBONE PATTERN OF 6" x 12" ACOUSTICAL MATERIAL

ADAPTATION OF STANDARD TILE IN CEILINGS

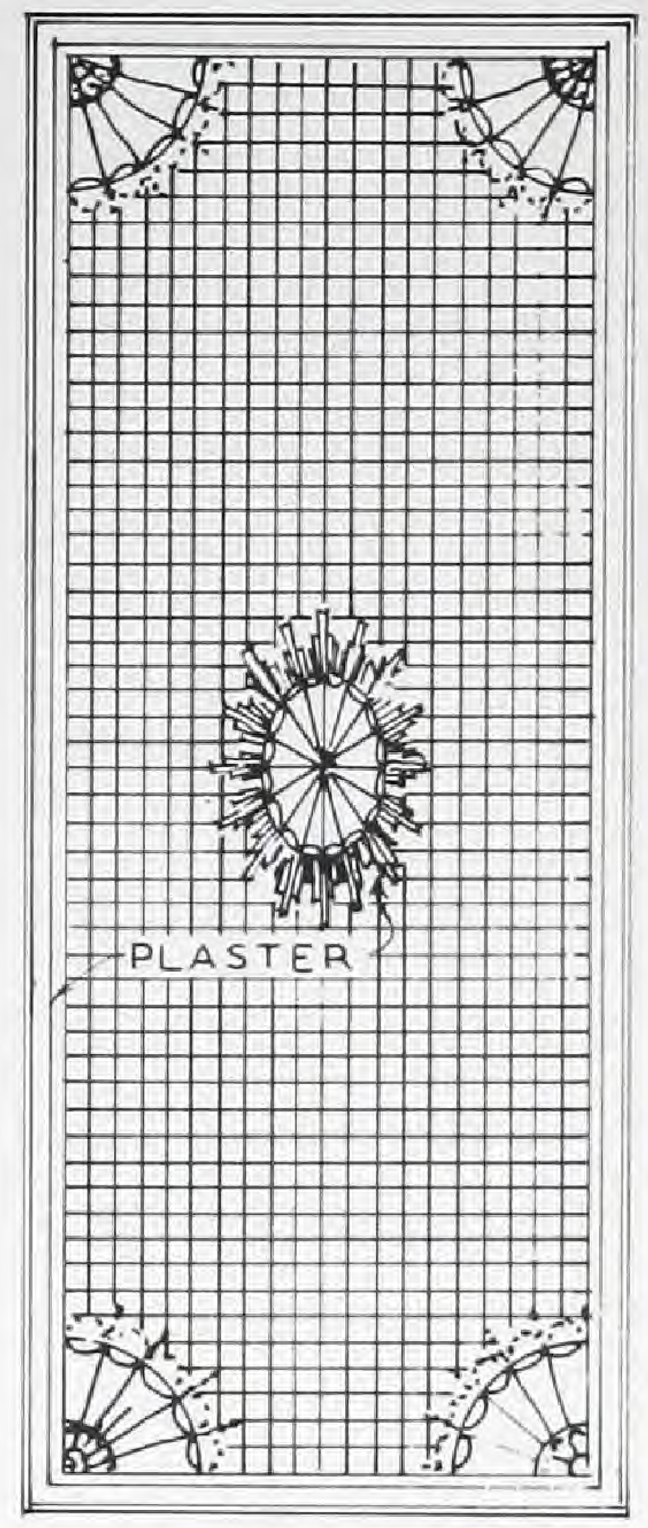
· EXAMPLES · OF · TRADITIONAL · ARCHITECTURE ·



· OLD ENGLISH

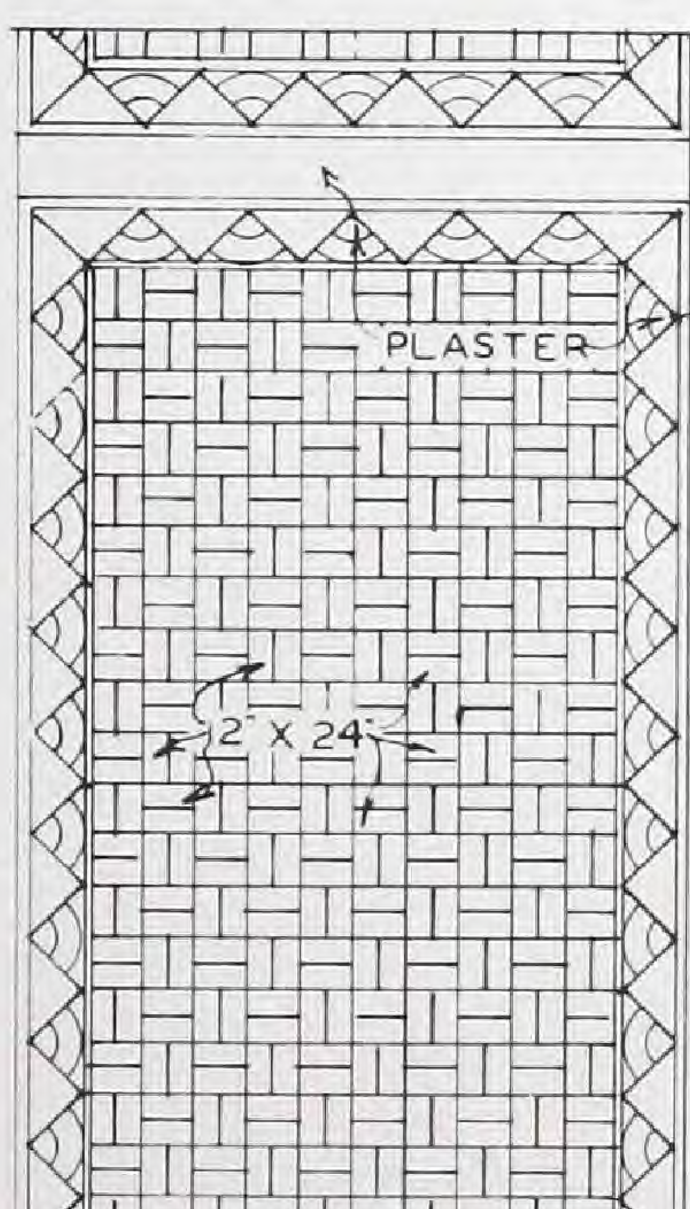


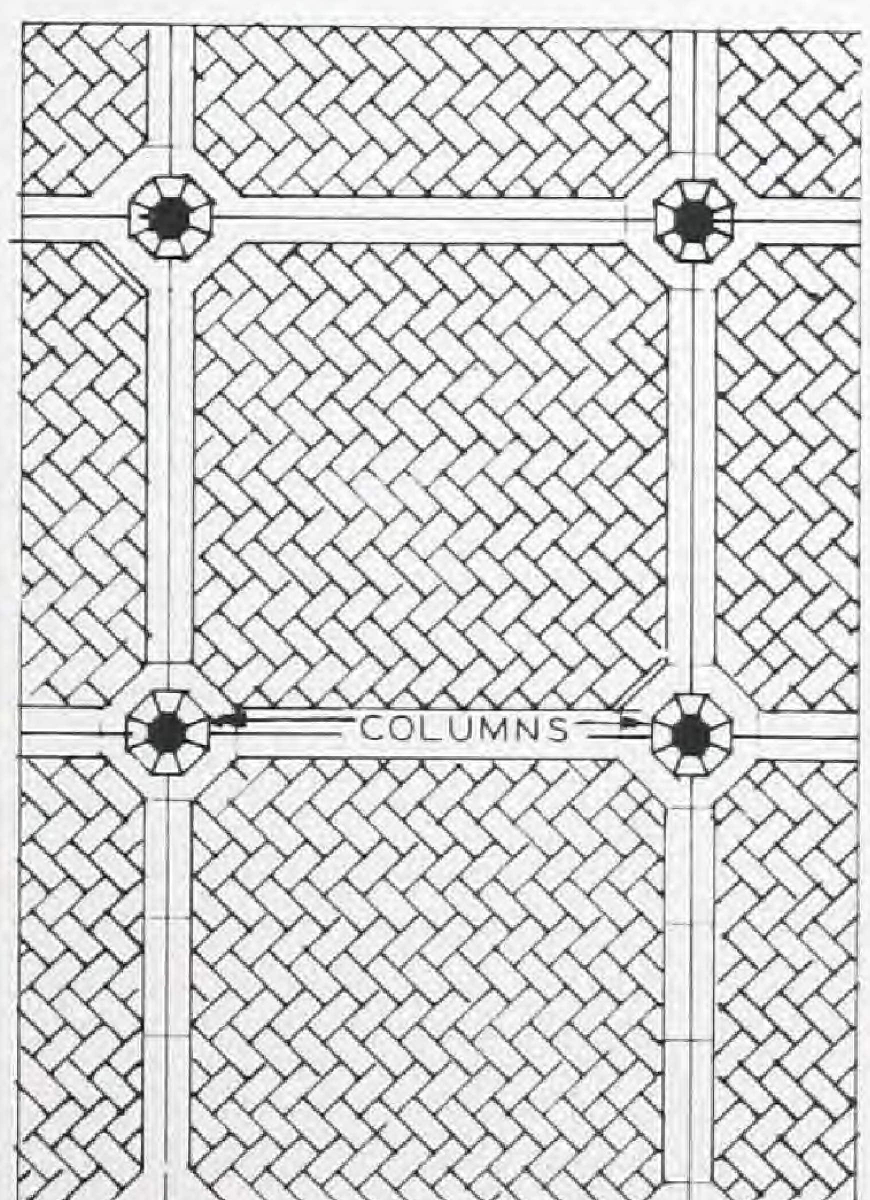
ITALIAN

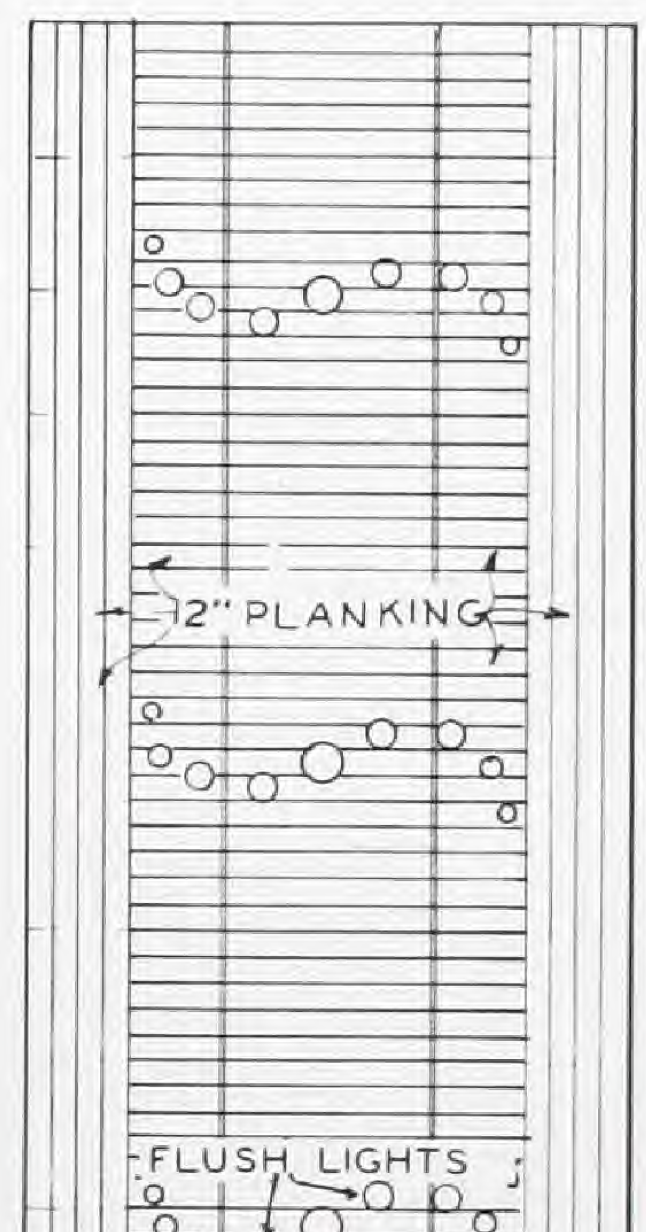


EARLY AMERICAN

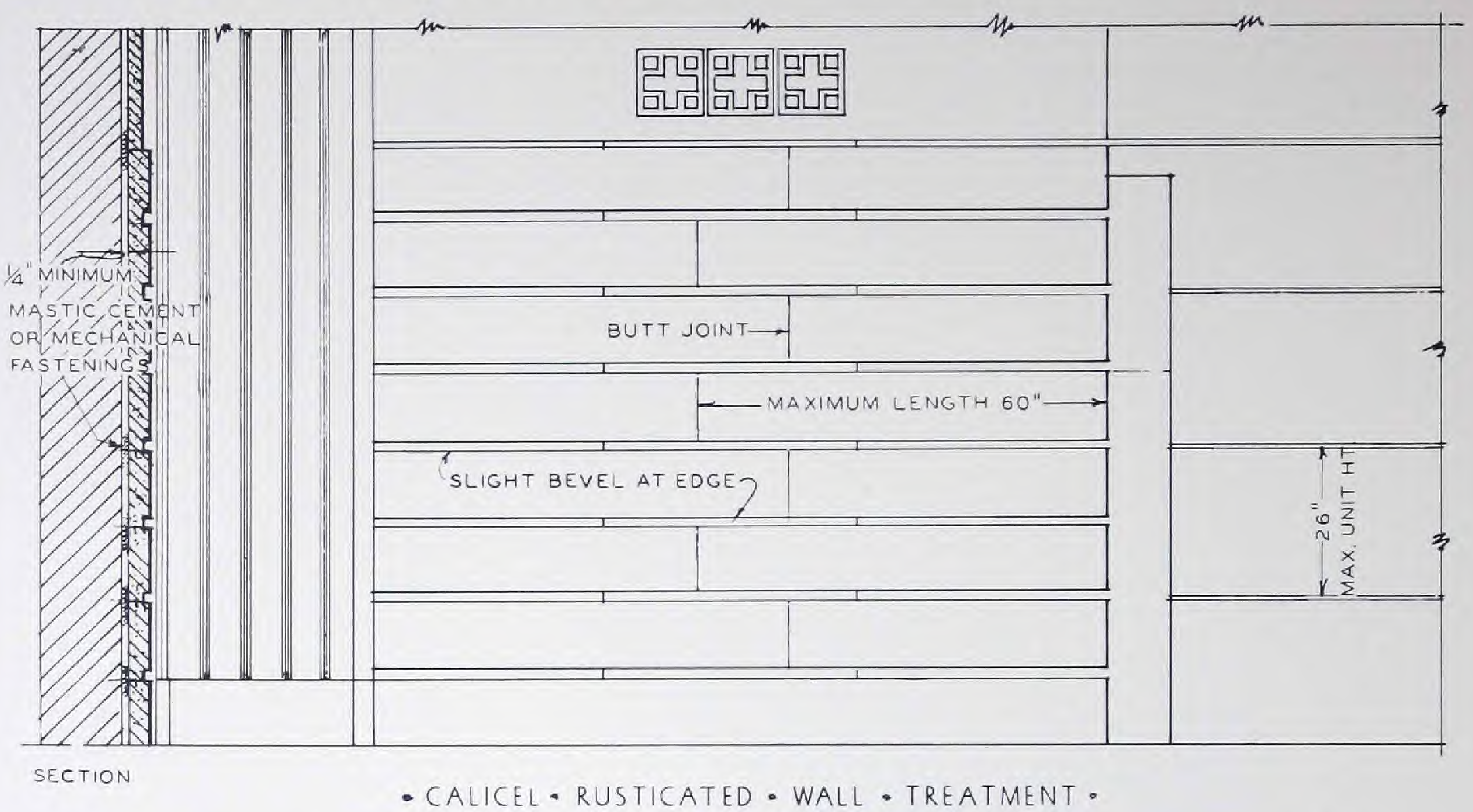
· EXAMPLES · IN · MODERN · STYLE ·





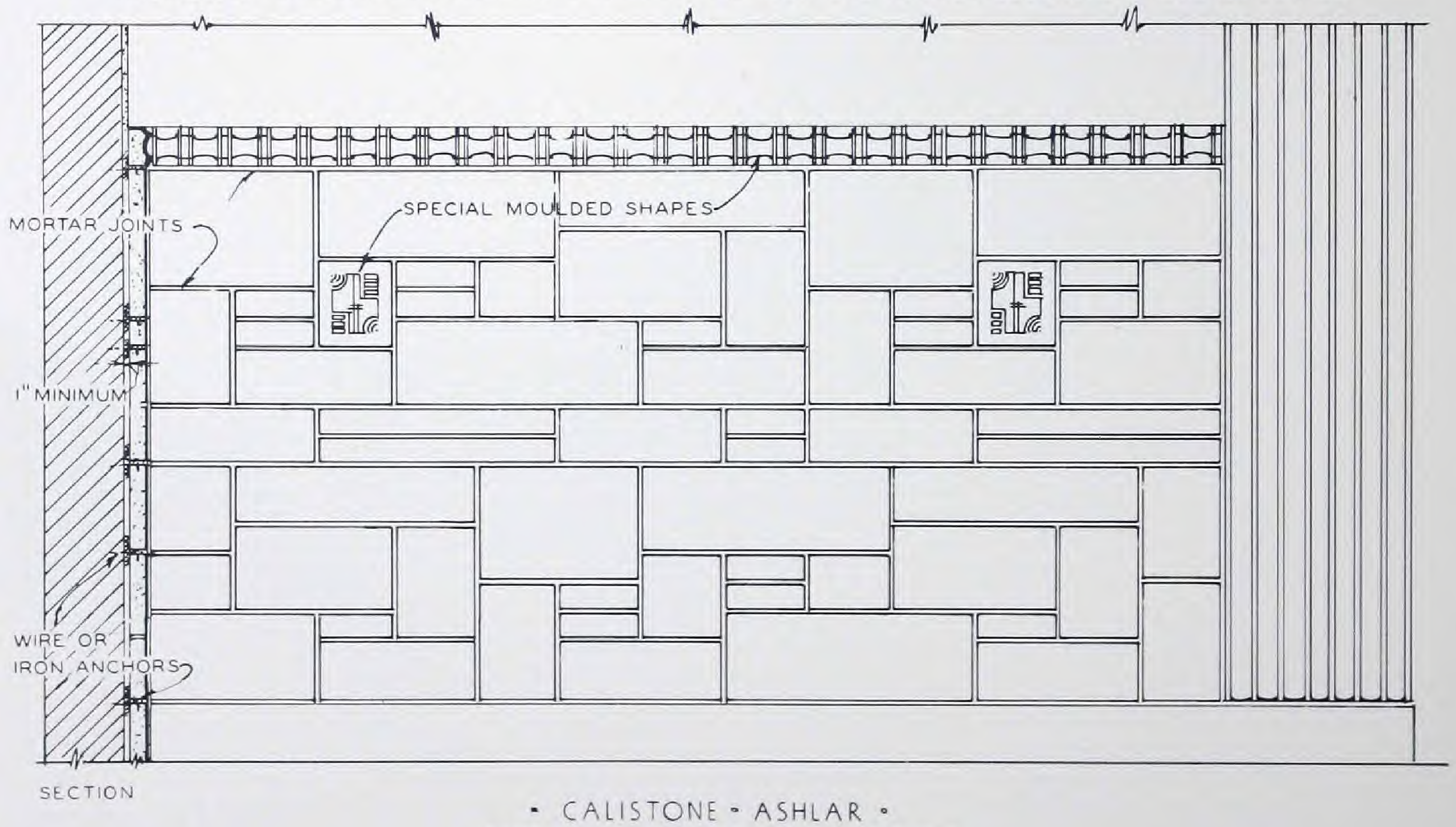


SUGGESTED WALL TREATMENTS



• CALICEL • RUSTICATED • WALL • TREATMENT •

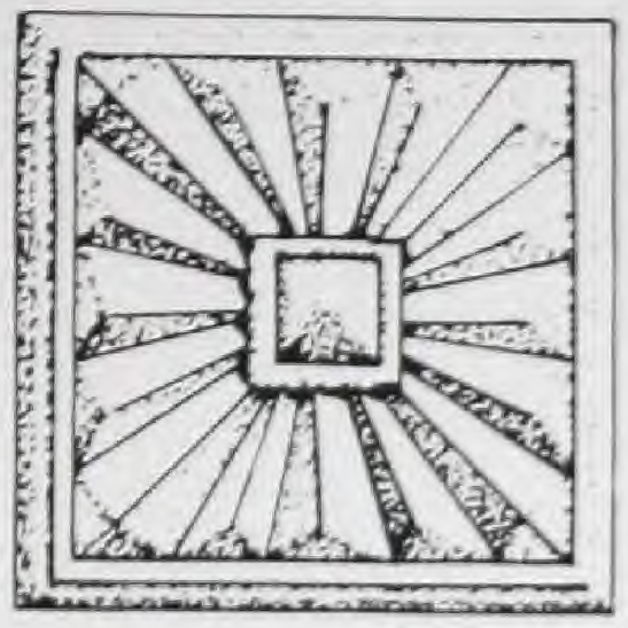
THICKNESS OF MATERIALS IS DETERMINED BY STRUCTURAL REQUIREMENTS AND ACOUSTICAL EFFECIENCY DESIRED



• CALISTONE • ASHLAR •

SAND RUBBED FINISH OR SPECIAL TEXTURES

VIBRAFRAM ACOUSTIC UNIT

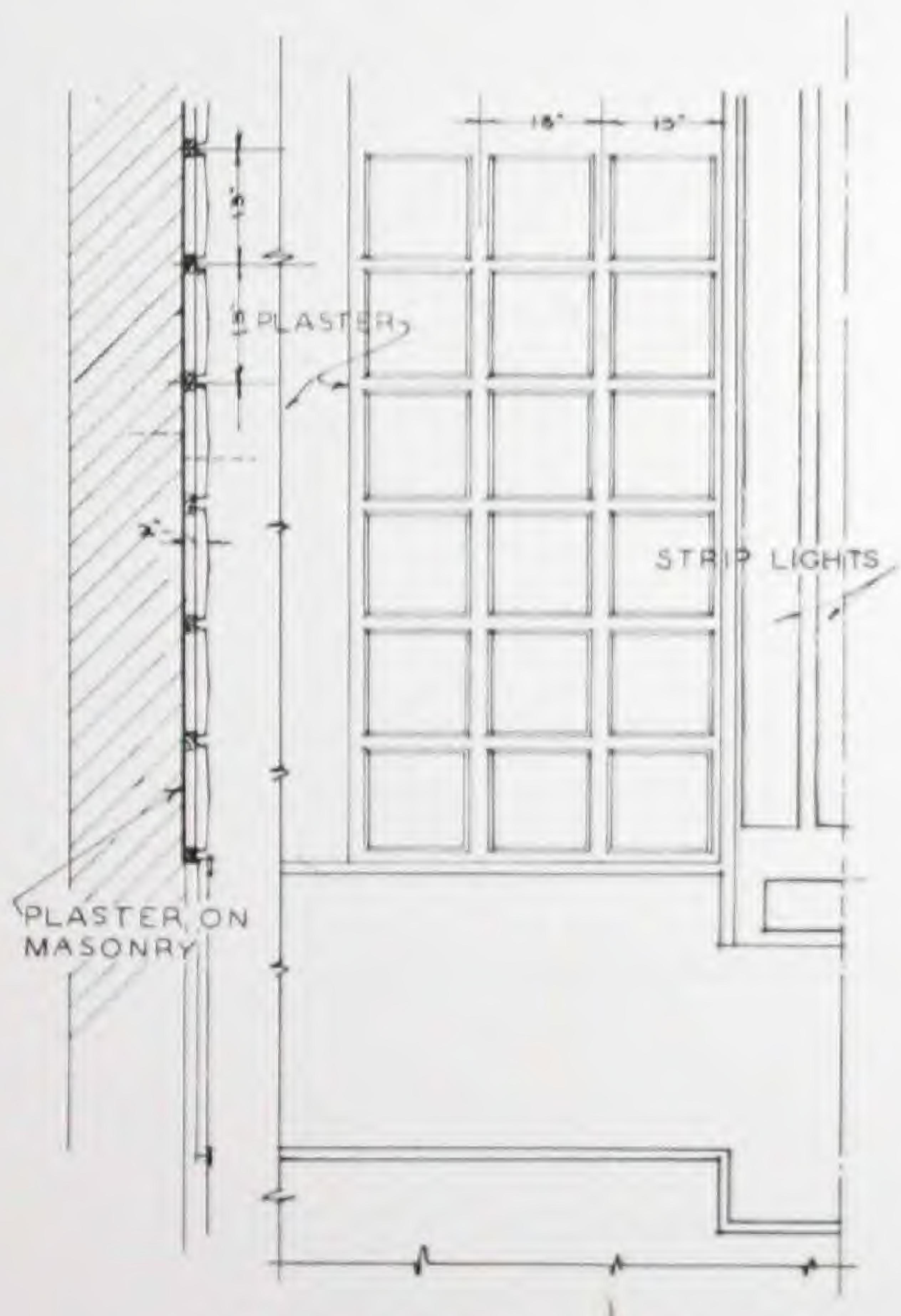


PATTERN C-6

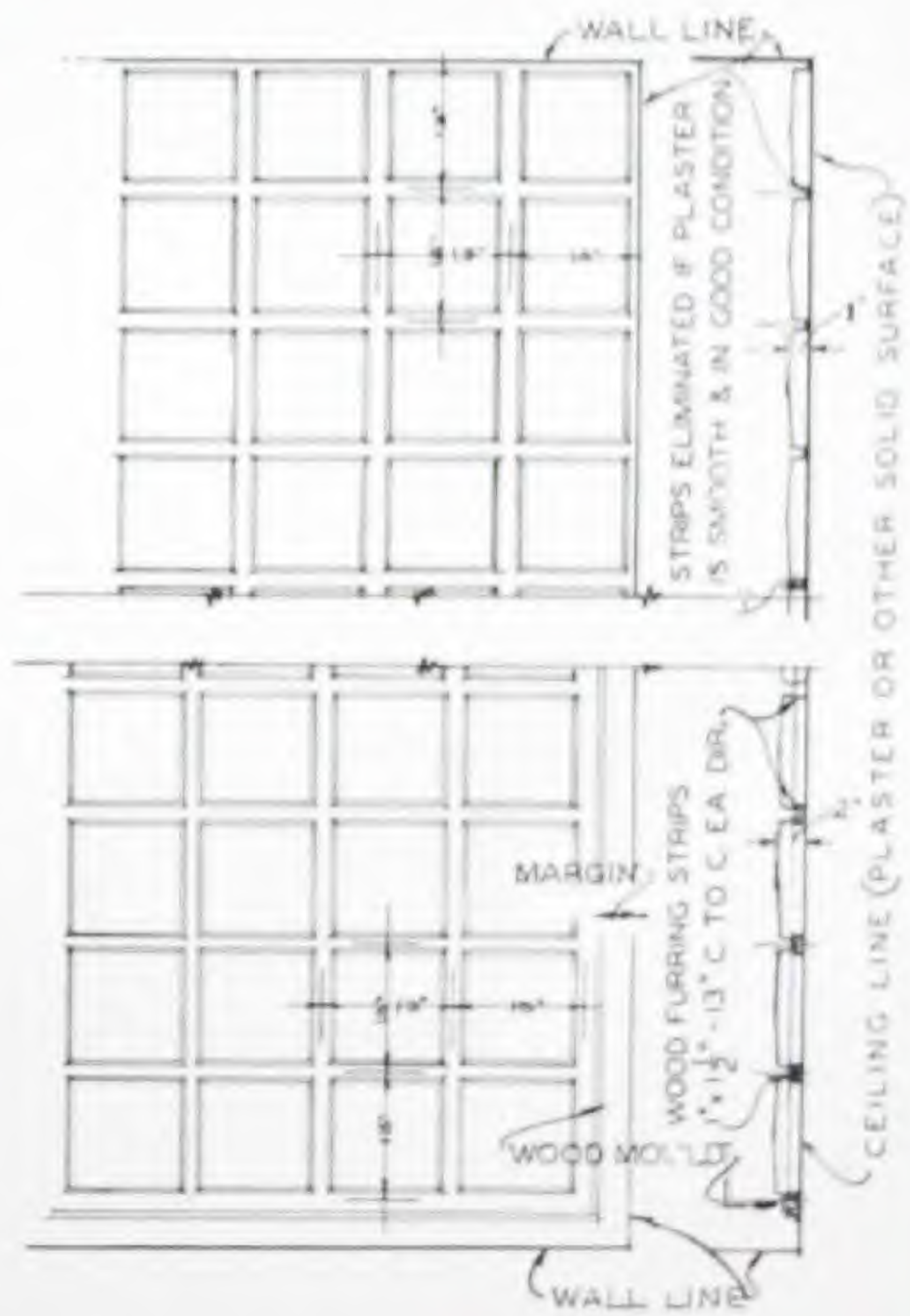
PATTERN E-1

PATTERN C-5

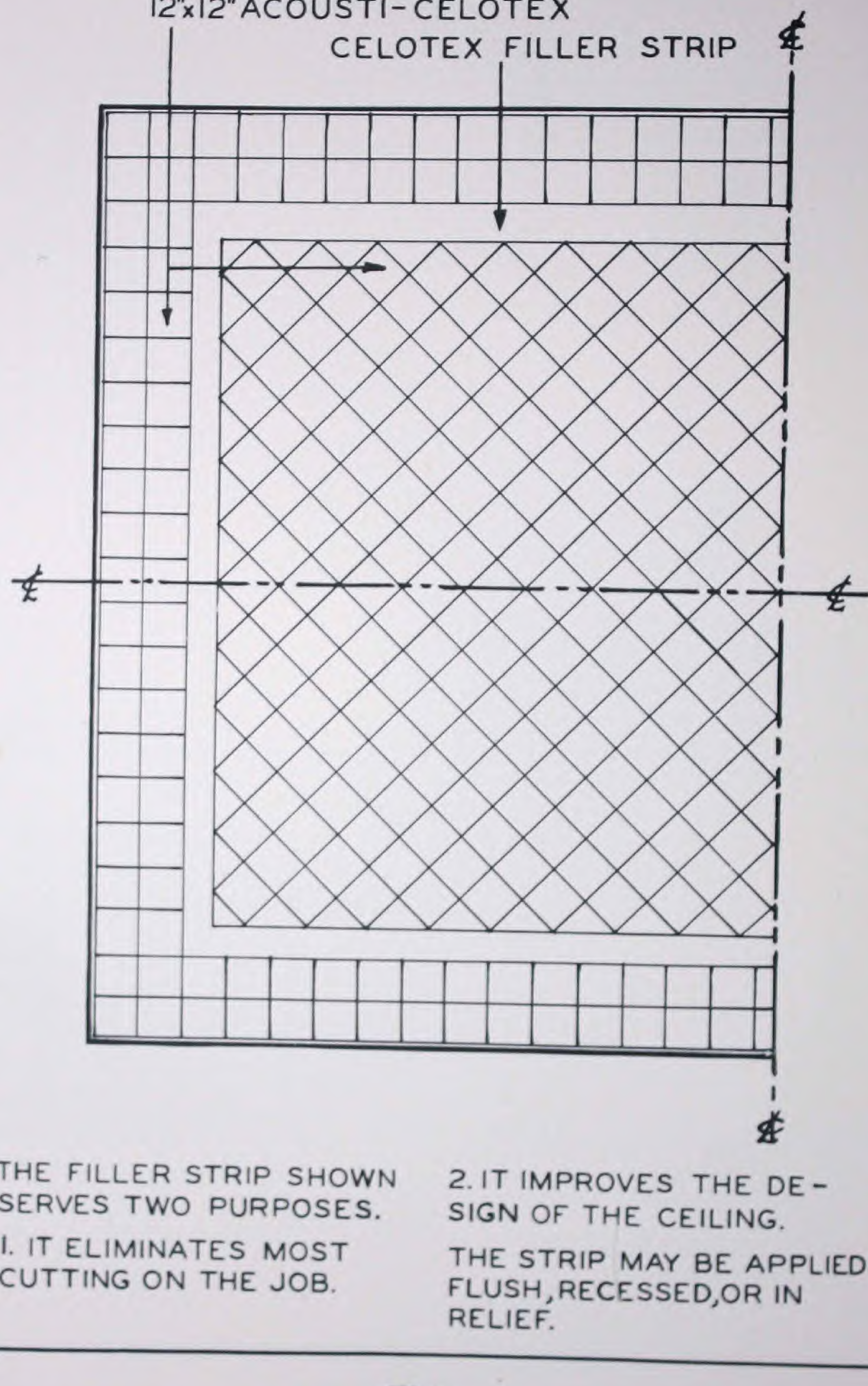
· PRESENT · TILE · PATTERNS ·



· APPLICATION · ON · SIDEWALL ·



· APPLICATION · ON · CEILING ·



THE FILLER STRIP SHOWN SERVES TWO PURPOSES.

1. IT ELIMINATES MOST CUTTING ON THE JOB.

2. IT IMPROVES THE DESIGN OF THE CEILING.

THE STRIP MAY BE APPLIED FLUSH, RECESSED, OR IN RELIEF.